Development of a Framework for Resource Planning and Allocation in Service Organizations

by

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Dedication

This thesis is affectionately dedicated to my parents, my wife Nawal, and my three children: Mohammed, Zayed, and Mansour for their perpetual spirit and encouragement to bring out the best in me.

Abstract

The use of modeling and simulation as decision tools in service delivery systems has been growing rapidly. Modeling and simulation methodologies have been used in order to capture the interrelationships among the factors and variables involved in resource management of service organizations. Although numerous initiatives have been put in place at both strategic and tactical levels in order to address the problems of escalating operational costs and increasing demand for quality of services, there is no reported general model that factors in the involvement of the principal stakeholders (management, staff, and end-users) in all stages of problem formulation and model building. Moreover, previous initiatives tended to provide optimal solutions that may be beneficial for one or more departments being investigated, but not necessarily for the entire organization as one whole integrated delivery system. In this thesis a new framework for improving resource management is proposed. The underlying principle of the new approach is based on the participation and involvement of all stakeholders at the early stages of model development. Additionally, the modeling process is an iterative one that is governed by the views and inputs of the stakeholders rather than by pre-specified requirements and objectives. Another important aspect of the proposed approach is that it provides a mechanism for evaluating system performance and identifying activities that have considerable impact on performance as well as activities that have minimum added value within the service delivery system.

Acknowledgments

I would like to take this great opportunity to acknowledge a number of people for their help and support during my research period. First of all, I would like to thank my two co-supervisors: Dr. A. O. Abd El Halim, The chair of the Civil and Environmental Department, and Dr. Samy Mahmoud, The Dean of Engineering and Design, for their support and help in carrying out this research. I also would like to extend my thanks to Dr. Linda Newton for her continual guidance through all phases of this thesis and acknowledge her contribution in this thesis. Special thanks is extended to Dr. Paul Van Geel, and Dr. Yasser Hassan for their practical and academic support during my research. Special thanks go also to the staff at both the Dean of Engineering and Design Office and the Department of Civil and Environmental for their support during hard times. I owe much to the Head of the medical services at Zayed hospital Dr. Ahmed Abdullah for his support. I am also grateful for the support I received from the medical staff in the departments and clinics selected in the case study for this thesis for granting me access to all the data and information needed.

Table of Contents

List of Tables

List of Figures

List of Appendices

Chapter 1

Introduction

This research explores in details the development and evaluation of a general framework to efficiently aid the process of resource management and allocation in service organizations. The term "improvement framework" used in this thesis refers to a new approach proposed in chapter three of this thesis, where discrete event simulation is used as an adequate tool for and analyzing a health care delivery system. The first part of this thesis is devoted to the development and evaluation of the general improvement approach. The second part demonstrates the application of the general approach to a specific service delivery system (health care delivery system) at Zayed Hospital in the United Arab Emirates.

The first chapter of this thesis provides a general overview of resource management issues in service organizations with a focus on health care organizations. Also discussed are the current problems and challenges facing service organization. The last part of the chapter is devoted to present the importance of and justification for this thesis and concludes with a detailed problem statement.

A comprehensive review of important issues in resource management including resource scarcity, consumer/producers' relationship, and the health care delivery system is presented in chapter two. Also explored in detail are the related research studies in health care resource management. Chapter three involves the theoretical aspect of the new proposed improvement framework. It also discusses the tools used for building the model including patient and work force satisfaction surveys; process evaluation forms, and presents the development of the model for the selected clinics and departments at Zayed hospital. The research methodology and experimental design are presented in chapter four. Chapter five is devoted to the results of the modeling and experimentation. Finally chapter six of this thesis sets out to present the conclusions drawn from this thesis and recommendations for future studies.

1.1 Resource Management

Service organizations currently are facing global competition ranging from being able to have a competitive edge with continual improvement while operating at low cost, to responding to customer demands. Overcoming these challenges is the key for survival in today's market. Moreover, resources are ultimately what distinguish one organization from the other and are the key elements through which organizations can gain an advantage over their competitors. It is difficult for organizations whose operating costs rely on high investment in resources to reduce operation cost, reduce complexity of workflow, and utilize the resources within the organization. Additionally, ensuring the availability of adequate and appropriate resources has been a challenge for decision makers in many organizations. In an attempt to overcome this challenge many organizations have applied simulation modeling as a decision support aid in planning and allocating resources. Consequently, making managerial decisions in the management and allocation of resources based on evidence by modeling efforts is certainly a step forward. Examples can be given of many successful applications in different fields including: natural resources, transportation and traffic management, human resource management, airports, construction sites, health care delivery systems, etc. The importance of modeling as a process rises from the fact that it enables management to predict the effect of changes prior to implementing them, evaluate different alternative policies of planning and allocation of resources, and forecast the future needs and demands in alignment with the predetermined goals and visions of the organization. There are three types of resources that are called factors of production including human, natural, and capital resources. The availability of an adequate supply of labor with the required skills and abilities is essential to today's thriving economy. Over the past two to three decades, there has been a shift toward human resources as a key factor in determining the success of organizations. People with the right skills, abilities, and knowledge are essential for organizations to effectively fulfill their goals and accomplish their strategic and operational objectives. Firms profess that people are the source of their competitive advantage, whether they are technological experts, accommodating customer service experts, or visionary managers [1]. While human resource management includes recruiting, compensation, and performance measurements, the key component of overall effective human resource management is the development and design of a framework of activities and practices that support and develop a motivated workforce, and ensure the effective and efficient use of available capacities in the organization. Natural resources are found in nature such as water, soil, oil, wood, and coal. The urgency of assessing, managing and protecting such resources has reached new levels. Several government regulatory programs now require explicit consideration and mitigation of natural resource impact on facility re-licensing, permits, and development planning. Moreover, the quality and quantity of natural resources that are available have an impact on the level of organization production.

Capital resources represent things that have been produced (man-made) such as machinery, tools, and buildings that are used in the production of other goods or to provide a service. They can be used over and over again in production processes. As they are used over and over, capital resources depreciate and deteriorate. Organizations must plan to replace capital resources due to the normal wear and tear they receive in the production processes.

1.2 Research Problems and Formulation

1.2.1 Health Care Cost

As was emphasized earlier, service organizations are under financial pressure to control operational costs while striving to provide quality of services, which they can gain an edge in today's competitive market. Faced with this challenge of meeting rising demands for higher quality of services while having limited resources, organizations tend to focus on finding the most effective and efficient strategies in allocating and managing their available resources such as workforce, equipment, facilities, and technology. Effective strategies mean how well the strategies accomplish the organization's goals and efficient meaning how much theses strategies cost compared to other alternatives for meeting the same goals. As is the case in many industries, the health care industry is no different.

Health care organizations are also facing the same challenges. Building and maintaining an adequate transportation system, providing a quality public education system, and assuring quality of health care services are the fundamentals that determine the pace of economic growth and quality of life in a country. Health care costs are becoming a significant challenge for governments in many countries. All developed countries are spending an increasing share of GDP on health care and are increasingly worried about cost control and quality improvement of health care services. In Canada, rapidly rising health care costs reached $121 billion in 2003[2]. When considering the rapidly increasing health care cost many factors come into play as cost drivers or indicators. These include population growth and aging, drastically increasing demand for quality and access of health care services, and technology advancement. Older people often experience a decline in physical and mental health. Resources for long-term care are under increasing strain due to the aging world population [3]. According to Statistics Canada [4] the median age of Canada's population has reached an all-time high of 37.6 years, an increase of 2.3 years from 35.3 in 1996. Similarly, in Britain issues related to the aging population and the rising health care cost exist [5]. It was found that by the year 2030, one-third of the British population will be over 50 years. Consequently, the proportion of the population over 65 grows larger and as a direct result, the demand for medical resources and health care services increases. Technology advancements are another cost driver in health care. Making more complex and costly diagnostic and therapeutic tools, and as technology improves, pharmaceutical research and development increases, leads to a rise in drug prices. With enhanced diagnostic and therapeutic capabilities, more complex disease processes were amenable to treatment, which in part led to the rise in specialists and consultative services. As stated in the Conference Board of Canada 2001 report [2], the key factor in overcoming productivity challenges in the health care industry is more government investment in research related productivity drivers including resource management, technology, and training.

1.2.2 Complexity

By its nature, the health delivery system is a very complex one that is largely driven by rapidly changing technology and information, requiring intervention from different health professionals, and is unique in all of its characteristics. It is unique from any other type of industry in that health care professionals are highly dependent on each other to provide and coordinate services of high value for human beings. This dependency is interconnected so that one action can change the context of other actions, as is the case in a primary health care team. The interactions of the parts of the team are not always predetermined and so consequences cannot always be foreseen or planned. This is especially challenging for health care managers who are responsible for managing and planning health care resources [6]. In addition to having to deal with providing quality health care services at lower cost, health care organizations deal with a wide range of social, financial, political, regulatory and cultural challenges[7]. Medicine itself is a high technology, science-based profession, constantly enriched by inflows of knowledge from the biological sciences, new drugs and treatments, and engineered innovations from the medical equipment industry. Ozcan and Smith [8] summarized the challenges that health care organizations are facing compared to other organizations, when trying to identify effective approaches in the management of health care resources as follows:

- great problems are attached to measuring the health outcomes of health care activities. Examples include: no standardized tools or outcome measurements and health outcome is subjective rather than objective
- hospital and other health care organizations often have complex organizational forms and systems of governance
- even when salaried, physicians demand a certain degree of professional autonomy
- extensive education and training needs must be accommodated
- technology and clinical practices change rapidly
- the health care product is highly complex, often needing to be carefully tailored to the needs of the individual patient

1.2.3 Sustainability

Another issue that justifies studying service delivery systems in health organizations is sustainability of health care services. A sustainable health care system would view health as an 'added value' outcome of social organization and explore the co-production of health within health care services. Sustainability is ensuring that sufficient resources are available over the long term to provide timely access to quality services that address the evolving health needs. Sustainability is a trade-off between levels of service and the availability of funds. Sustainability should be defined in terms of whether the Medicare model can provide the financial means to pay the costs associated with present and future demands for health services. Another consideration is whether these financial means are politically and economically acceptable [9]. Health care organizations are now experiencing a so-called cost containment dilemma. Unsustainable health care system means reaching the point where spending is too high to be sustained. A sustainable system must both control costs and provide timely access to appropriate health care services. With the rapid increase of health care spending, rising consumer demand for highest quality, a dramatically aging population, technological developments, and advances in medical research and new treatments, sustainability is not guaranteed. One example of the non-sustainability in health care systems is the case of Ontario hospitals. A report by the Ontario Hospital Association (OHA) indicated that 35 hospitals in Ontario reported an operating deficit of $78 million in 2001 while in the previous year the deficit was $47 million for 69 hospitals. Additionally, an annual report by the Fraser Institute [10] highlighted the waiting time for health care services as a symptom of non-sustainability. The report indicated the following facts about health care accessibility:

- total waiting time for treatment by a specialist after referral by a general practitioner (GP) in 10 provinces was 16.2 weeks in 2000/01 and 16.5 weeks in 2001/02;
- total waiting time for consultation by a specialist after referral by a GP was 7.2 weeks in 2000/01 and 7.3weeks in 2001/02;
- total waiting time between consultation and treatment was 9 weeks in 2000/01 and 9.2 weeks in 2001/02.

In this context, the need for health care decision makers to devote more attention to find optimal resource management strategies that reduce cost, increase accessibility to health services, and provide quality services is essential if health organizations are to survive. Appropriate planning and management of resource practices is the key for ensuring access to the health providers now and in the future.

1.2.4 Health Litigation

The health care profession is subjected to many social, legal, and ethical layers of accountabilities and rules and is plagued with numerous costly lawsuits. For example, the patient-physician relationship revolves around economic, social, legal and institutional factors, which are also affected by the decisions made in that relationship [11]. Bowen et al. [12] indicated that the concepts of distributive, procedural, and interactional justice used heavily in industrial/organizational psychology and organizational behavior are applicable to health care organizations especially in the area of treatment, services delivery, and service recovery of patients. They emphasized that the foremost justice concern that customers have in the areas of service delivery and service recovery is the firm's fulfillment of its obligations in terms of the delivery of promised results or benefits. Additionally, they indicated that the four procedural justice principles in service delivery involve responsiveness to unusual requests, efficiency, waiting time, and helpfulness. Interestingly, these authors reveal that excessive waiting time was identified in customer service research to be the most significant customer dissatisfaction predictor. When procedures meet or exceed customers' expectations, they are considered by the customers to be helpful. Moreover, Bowen et al. [12] discussed six procedural justice principles with respect to service recovery: assuming responsibility, timing/speed, convenience, follow-up, process control, and flexibility. The service firm has to accept accountability for failing to initially deliver the service to the customers' expectations. The firm has to handle customer's complaints in the most expedient way. Service recovery has to be convenient to the customers. The recovery procedure should include follow-up or phone call which shows that the firm cares.

Complainants have process control when they can participate in the service recovery procedures by describing their unfavorable service experience and deciding upon reparation. Flexibility refers to the service firm's willingness to handle customer's complaints with flexible procedures. Brody and VandeKieft [13] stressed that a physician's decision for one patient affects all the patients in the health plan sharing the same resource base. In addition, they claimed that a physician should serve as an advocate for the individual patient and conserve resources to provide adequate medical care for all patients in the health plan.

In general, in the presence of uncertainty, assuring sufficient resources and sustainability of access to quality of health care services, fulfilling social, ethical, legal obligations and attempting to gain an edge in today's competitive market are real challenges for health care organizations. Moreover, failing to provide health care services at the right time is costly and can mean a difference between life and death.

1.3 Problem Analysis and Research Justification

The studies in health care resource management can be classified into two broad non-overlapping categories: (1) studies involving prevention, health promotion, and a cure for various diseases; and (2) studies involving the development of general hospital delivery systems, hospital bed planning, facility design, staff scheduling, optimizing patient flow, admission control, appointment system, patient flow patterns, and forecasting demand for health care services. The first category involves public awareness and education; improvement of health style, immunization, screening programs for various diseases, surgical management, and medical management. Although, there are opportunities for reducing operational costs and improving quality of health care services through research in this category, management generally is not trained in this area. Therefore, it is not the focus of this study. The second category is found to be too broad to be a subject of a single research study. A comprehensive review of this category can be found in chapter (2) of this thesis. The brief discussion here concerns the attempts that have been taken by different researchers to investigate resource management related issues in health care.

Several studies have been performed in an attempt to model health care service systems as a general system. The focus of these studies was mainly the management of patient throughput and admission in hospitals and facility design. Other studies related to individual health care delivery systems have focused mainly on the hospital and particularly, individual departments, which only constitute part of the hospital. Surprisingly, none of these studies were conducted with involvement of end-users, management and staff. These studies have considered problems such as bed occupancy, facility design, staff scheduling and planning, admission and appointment control, and patient flow patterns.

To conclude, although resource management studies that investigated specific departments exist, there is no reported general approach that enhances the involvement of patients, workforce, and management in the stages of problem formulation and model building. Moreover, the studies tend to provide optimal solutions, which may be beneficial for the department investigated but not necessarily to the hospital as a whole. Another limitation of these studies is the unavailability of a post evaluation mechanism to measure the efficiency of alternatives if they were to be implemented.

Other factors that contribute to the justification of this study, is the growing importance of bridging the gap between consumers, clinicians, and health care managers. There is considerable evidence supporting this avenue[9] to [14]. Geoff [14] indicated that one of the forces driving the shift in when, where, and how health care services are delivered is the change in public expectations. This rises from the fact that patients increasingly expect to be more involved in decisions about what sort of treatment they receive, when they get it, and where it will be given. Sanchez et al.[15] discussed the emerging issues for achieving success when considering computer simulation modeling for improving the health care delivery systems. One of the important issues was to understand the patient needs and provide them with answers to their problems. The second important issue was the involvement of management and clinicians in problem formulation as an initial stage in the whole modeling process, as well in assisting in overcoming any conflicting objectives, and buy-in challenges. Hill et al. [16] claimed that a number of approaches have been developed to efficiently enhance the involvement of patients in the process of planning and delivering health care services. The validity of these approaches emerges from the fact that there is a strong drive toward greater community participation in the range of both national and local government organizations. Eldabi et al. [17] suggested that in the complex health care systems where conflicting objectives, needs and problems between managers and clinicians are common, efficient intercommunication is the key factor in solving such problems. Stevenson et al. [18] conducted a study to stress the need for patient partnership with health professionals in planning health care resources. At the initial stages of the study it was found that the nine participating practices had a tendency of overestimating services of no value-added to patients and as a result 40 changes of service provisions were made. In reviewing simulation as an adequate tool to assist decision makers in the management of health care resources, Wilson [19] found that out of two hundred models, only sixteen reported having successful implementation. One of the recommended solutions to overcome implementation challenges and increase the chances of successful implementation is the participation of the decision makers in the model development process at early stages. In general, reviewing these studies has set the stage for the development of the discrete simulation model that is analyzed in the following chapters of this thesis. The justification of this proposed research is summarized below.

- The rapidly increasing health care cost, scarcity of health care resources, complexity due to multiple decision makers within health care systems, and non-guaranteed health care sustainability over the long term, have been identified by governments and researchers as important areas for worthwhile and urgently needed research.
- Although numerous initiatives have been put in place to aid resource management planning and allocation in service organizations, no general framework that accounts for problem owners involvement, provides a post evaluation mechanism, and incorporates a continued data improvement process has been reported.
- The rapidly increasing demand for quality of services while service organizations are experiencing economic scarcity because of the limited resources needs to be addressed.
- It has been shown that the area of resource management has, and continues to be, interesting for many government agencies and researchers.

Research contribution to the health care field can be summarized as follows:

1. This research will be the first to develop and explore a general resource management framework with the involvement of stakeholders including management, workforce, service end-users, and the analyst;

2. The proposed framework will be the first to provide a mechanism for assuring continues data improvement throughout the modeling efforts;

3. The new approach will be the first to provide an effective and efficient measure to observe the consequences of implementing new resource management policies or planning strategies; and

4. The methodology and techniques developed in this research will be valuable to similar research studies after certain modifications.

1.4 Summary of Problem Statement

There are strong indications that the involvement of consumers and staff in model development stages is a key factor in improving the coordination between different resource planning efforts. Additionally, it has been shown above that enhancing participation among health professional, customers, and the analyst throughout the modeling process, is essential in understanding the customer needs and addressing the real problem reasons and issues related to the delivery system. Consequently, overcoming any implementation barriers and buy- in challenges can be accomplished. The research described in this thesis is primarily directed at developing a general modeling approach to support resource management decisions making (planning and allocation) in service organizations with end-user, working staff, and management involvement throughout the approach development process. The application of this approach is directed at a specific health care setting (hospital). This area has been chosen for the following reasons:

1. The health delivery system has a high sensitivity to errors and there are major risk factors associated with system failure due to the unavailability of certain resources.

2. It is a technology oriented delivery system.

3. The delivery of health care services is shifting from an inpatient to an ambulatory setting. This shift is a combined by an increase in pressure to improve the quality of health care services in outpatient clinics [20], [21].

4. No other general approach that considers the involvement of end-users, working staff, and health management in the modeling process has been reported in detail.

5. There is growing interest in many countries for directing research efforts to find effective and efficient health care resource management practices in health care organizations in an attempt to reduce operational costs and improve the quality of the health care services provided.

6. The importance of time value in the delivery of health care services.

In summary, the problem investigated in this thesis is the occurrence of under or over utilization (mismanagement) of resources (human and capital) due to the inadequate planning and allocation mechanisms in the hospital setting. Additionally, the impact of such practices on patient waiting and service time is investigated. This thesis attempts to answer the following questions:

1. What are the dependencies between resources in service delivery systems?

2. What is the variation in the use of resources including human and capital resources?

3. What is the impact of the current resource planning and allocation practices on these variations?

4. What are the requirements of an adequate resource planning and allocation mechanism, and how can they be implemented?

5. What is the effect and overall trend of involving customers, organization management and staff in developing new resource management mechanisms using simulation as a tool?

6. What are the basic measures of effectiveness and efficiency for planning and allocating resources in service organizations, and how can they be used to analyze and redesign the current resource management practices?

1.5 Research Objectives and Deliverables

The research objectives can be summarized as follows:

- Design a general framework to aid the decision of resource allocation and planning in a service organization and enhance the efficiency of service delivery systems;
- Study the health care delivery system;
- Apply the developed general framework to the health care delivery system;
- Evaluate alternatives and recommend solution(s).

In summary, the main theme of this research is to develop a generic simulation model using the new proposed improvement framework in an attempt to efficiently aid resource management decisions in service organizations. The application of the model will be used in a concrete case to:

1) Analyze the existing service delivery system at Zayed hospital in the United Arab Emirates;
2) Evaluate different operating and resource planning alternatives;
3) Observe the consequences of changes in resource planning policies prior to decisions actually being implemented;
4) Demonstrate how to enhance the effectiveness and efficiency of the services provided;
5) Develop service performance measures and quality indicators;
6) Enhance and improve communication among management, workforce, service end-user, and the analyst; and
7) Reshape end-users and workforce perception and expectations about the service delivery system.

Chapter 2

Literature Review

2.1 Introduction

While there is much complexity and uncertainty in managing resources, there is considerable agreement on the factors that contribute to the success, activities and processes that need to be undertaken if an effective and efficient resource management mechanism is to be implemented and to sustain the operational strategy at a lower operational cost and high quality over time. Reviewing the topic of resource management in this chapter will start with reviewing important issues including scarcity of resources, producer/consumer relationships, and the components of the health care service delivery system in sections 2.2, 2.3, and 2.4 respectively. Section 2.5 gives insight into the hospital production process and patient flow throughout the health care delivery system. Section 2.6 reviews the concept of quality in health care and the importance of the involvement of the key players in defining the quality dimensions within the health care delivery systems. Explored in section 2.7 are the modeling techniques that have been used to investigate health care delivery systems and efficiently manage resources. In section 2.8 the related studies in resource management in health care organizations with the focus on discrete event simulation as an adequate tool are reviewed. Lastly, in section 2.9 a conclusion of the related studies that have been reviewed in this chapter will be presented.

2.2 Scarcity of Resources

Scarcity refers to the tension between limited resources and unlimited wants and needs. For an individual, limited resources include time, money, and skill. For a country, limited resources include natural resources, capital, labor force, and technology. Because all our resources are limited in comparison to all our wants and needs, individuals and nations have to make decisions regarding what goods and services they can buy and which ones they must forego. Of course, the values of each individual and nation are different, but people and nations, each having different levels of (scarce) resources, form some of their values because they must deal with the problem of scarcity. So, because of scarcity, organizations must invest time, effort, and money in finding the optimal decisions in how to plan and allocate their resources. The famous definition for scarcity was given by Robbins [22] as the condition where the quantity desired of certain resources exceeds the quantity available. We experience economic scarcity because our resources are limited, and our wants are unlimited. For example an increase in natural resources scarcity is defined as a reduction in economic well being due to a decline in the quality, availability, or productivity of natural resources. This scarcity forces us to make choices about how to use our limited resources. In organizations, the fundamental challenge is to balance between productivity and availability of resources, such as human and capital resources, required for production.

2.3 Producer/Consumer Relationship

As stated previously, scarcity is the unavailability of certain resources to satisfy all of our wants at the same time. Everyone, whether in their role as a producer or a consumer, must make choices about how to use the limited resources available. Producers combine human, natural, and capital resources to produce goods and services. Producers must decide what they will produce from the limited amount of natural, human, and capital resources that are available. The availability of those resources influence decisions about where the producer locates for production, how much of the goods or services will be made available for consumption, and the price for the goods or services. Similarly, consumers - people who use goods and services-experience scarcity. Choices must be made about what and how much to consume. Consumers must decide what to buy/use with the limited amount of money they have to acquire goods and services. On occasion, a consumer may have the monetary resources to make a purchase but find that the goods or services are scarce (unavailable). Both consumers and producers have their own perceptions and expectations of the services or product and normally there is a communication between consumers and producers to bridge the gap between them. Understanding consumer's needs and expectations is not only important for what goods or services should be delivered but also when these goods or services are delivered. This can be achieved by a two-way exchange of information as shown in Figure 2.1[20].

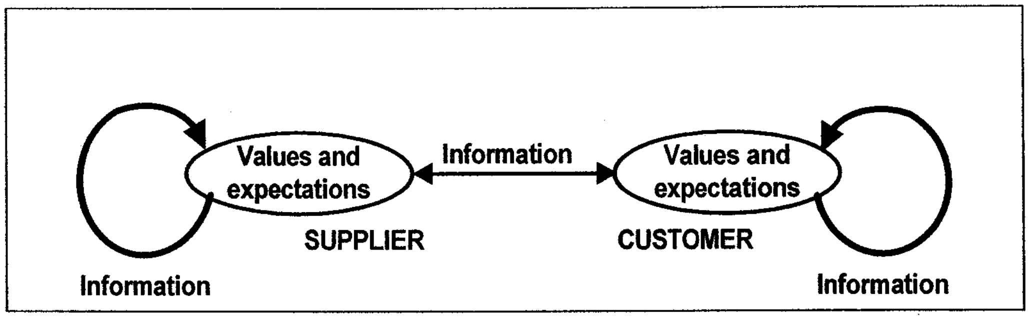


Figure 2.1: Customer/supplier relationship [20].

It is also important to note that individuals and departments within the organization are interconnected since their acts are intended to benefit customers and as a result the organization. Realizing that managing the consumer/producer relationships effectively will generate real value for both consumer and producer alike, organizations have put more emphasis on this relationship. Their objective is to create additional value and drive competitive advantage by ensuring effective management of resources needed to achieve a given demand. Matching this given demand by making optimal decisions in planning and allocating resources is often the key factor in efficiently reducing operational cost, and increasing the quality of goods or services provided. To provide insight to the importance of reducing the imbalances between demand and supply in achieving the optimal use of available resources through improved allocation and planning of resources to where they are most needed and give the best value for money, one can use the illustrated demand and supply curve in Figure 2.2.

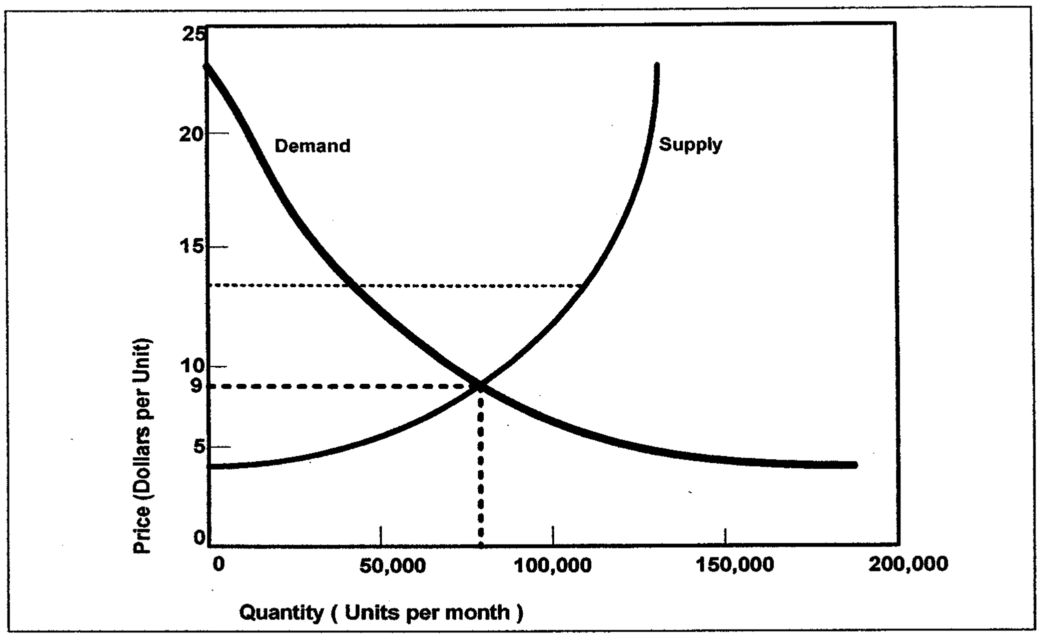


Figure 2.2: Demand and supply curve for competitive market[23].

As it is shown in Figure 2.2, the curve contains data that determine the price and quantity of the goods or services that will be produced. The supply curve represents the capabilities of the producer to produce goods or provide services profitably, where the demand curves represents the wishes and demand of customer for goods and services. If the demand for goods or services is greater than the supply, there will be a shortage in meeting this demand. If supply is great than the demand, the resources are being wasted. When supply and demand match, this is called market equilibrium. Market equilibrium exists when the price is high enough so that the quantity supplied just equals the quantity demanded. This equilibrium and corresponding quantity of production that would be traded in market equilibrium are the unique value toward which a competitive market tends to move. In the figure, this is where the supply and demand curves cross.

2.4 Health Care Delivery System

A health care delivery system at a micro level can be structured as shown in Figure 2.3 [24]. In such systems, inputs from suppliers, providers, and patients are fed into value added clinical and management processes and combined with enabling technologies to produce intermediate health products or services. These services are then organized and directed toward selected areas of demand or need in the health care system. The health care delivery system outcome can then be measured by the health status of patients, their perceptions of their experience, and the cost performance of the delivery system. In an optimal health care delivery system, the right mix of health care services is available in the right time (access) for the right needs (demand) to be used (utilized). Therefore, decisions within the health care delivery system related to clinical and management processes are essential in the system performance and outcomes. This involves making appropriate and consistence choices regarding infrastructure and structural issues. Structural issues include capacity, facility design, clinical and process technology, and location. Infrastructure issues include issues related to aspects of system operations including process improvement methods, human resources policies, and planning and control systems. In general, health care organizations develop unique service system strategies to meet individual needs and target-market requirements. Such strategies should be consistent with the organization's vision and mission and underline all key design and process-oriented decisions. Moreover, they should be used to identify effective and ineffective health care delivery methods and procedures to achieve the optimal use of available resources through improved planning and allocation.

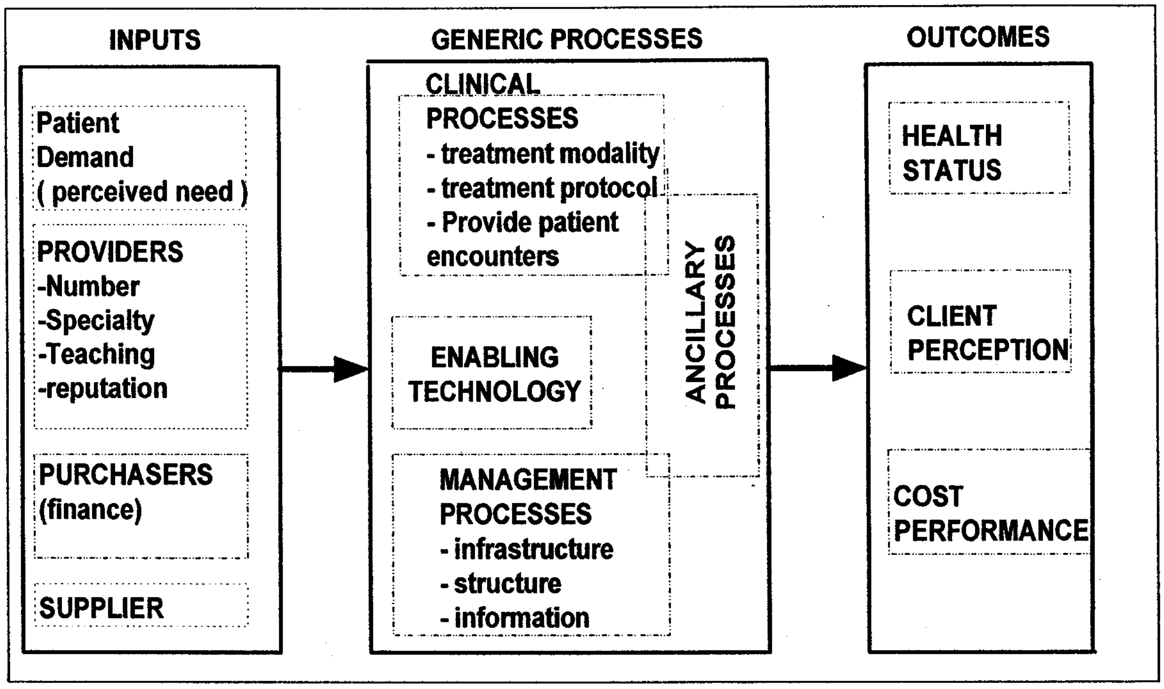


Figure 2.3: Meta-Process model for health care delivery system[24].

2.4.1 Health Care Resources

The success of any organization lies in its ability to satisfy the changing and growing needs of the population through efficient management of resources it uses; a task that involves the exercise of appropriate control over the consumption of resources. This is particularly true for health care organizations where various factors such as ageing population, rapidly increasing demand for health care services[3], and constant technological innovation, are leading to exponential growth in health care expenditure. Providing a health care service at a clinic or a department involves various resources. These resources are inputs for the management and operational processes at each clinic. They can be categorized as: (1) personnel; (2) facility (locations); (3) medical equipment and technology; and (4) materials. Of these human resources are the most important because of the scarcity of the trained medical personnel, and because labor is always the single biggest expense item in most of the health care delivery systems [2]. On-duty health professionals and staff receive compensation even when idle; similarly, maintenance of medical equipment must be absorbed even though the equipment is idle much of the time. The optimal use of these resources contributes to improving the efficiency and effectiveness of the health care delivery system and lowering operational cost.

2.4.2 Resource Capacity

To provide insight into the over/under utilization of resources, the concept of different capacitates we will explored in details as shown in Figure 2.4 [25].

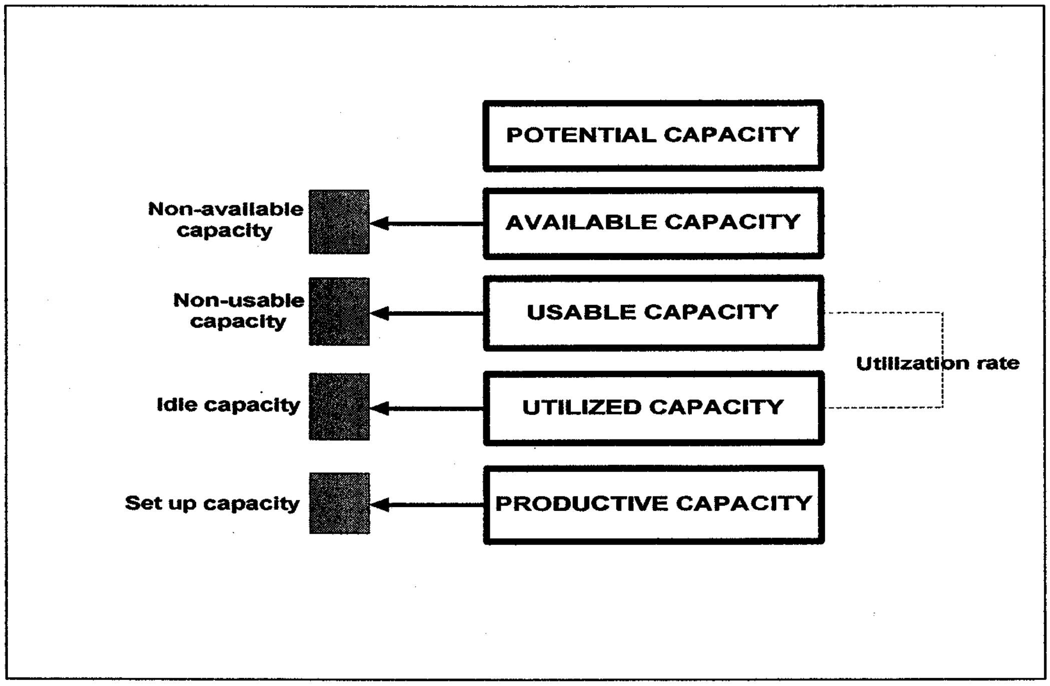


Figure 2.4: Capacity concepts for resources [25].

Potential capacity is the total amount of resources available of one resource unit type. When part of the potential capacity is not in use it is labeled as non-available capacity. On the other hand, available capacity represents the total capacity available for production processes. When part of this available capacity is not available for use because strategic planning and resource management restrictions, it is called non-usable capacity. Usable capacity can be defined as capacity available for production processes and normally used to calculate resource utilization. When part of this usable capacity is not used in the production processes because there is no work available, it is called idle capacity. Utilized capacity can be defined as the part of the available capacity that is actually used for production processes. If part of the utilized capacity is allocated for non-value added activities during production processes, it called set up capacity. The remaining capacity is called the productive capacity.

2.5 Hospital Setting

The activity of resource planning and allocation in health care organizations can be where allocated resources create the conditions for the daily production cycles. How resources are planned and allocated is the key factor in the delivery of the daily services. In many health care organizations, planning and allocating resources often lack rational basis. The allocation practices usually are based on historical right of specialties rather than patient demand, needs, and satisfaction. This can create under/or over estimation of demand and as a result under or over use of health care resources. Another factor in the hospital production processes is the timing of resource allocation. The unavailability of resources when needed for a production cycle can result in higher workload, more delays in providing services, and troughs in the need for resources. Similarly, the wrong coordination of shared resources between specialties such as diagnostic departments (lab and x-ray) can result in loss of resources, delays, and higher workloads. As defined in the earlier chapter, resources are objects that are used in a production process. For the purpose of this research the resources considered in this study are restricted to the more general type of resources like staff number and time, equipment, and locations (rooms). Equipment such as x-ray equipment at the emergency is only taken into account as a resource as far as it is linked to room availability. Additionally, another focus of the study will be directed toward shared resources in diagnostic departments including x-ray and laboratory. Sharing of resources occur when different product/or service lines used the same resources in a production cycle. Examples of this in a health care organization setting are many. Emergency patients in need of immediate care can be transferred to the radiology department for x-rays at un-predicted times. Similarly, walk- in patients at outpatient clinics requesting a certain specialist can be transferred.

The flow of patients through the hospital is the core process of the hospital production cycle. A typical simplified illustration of the production processes and patient flow through a hospital is shown in Figure 2.5. As illustrated, patients can enter the hospital in different ways. Normally, most patients enter the hospital via the outpatient clinics. If tests and exams are required for diagnosis and treatment, patients are referred to the diagnostic departments such as radiology and laboratory. Treatment can then take place at outpatient clinics, including different therapies or one- day surgery, then patients return home or to inpatients wards where patients are admitted for treatments. Alternatively, patients requiring immediate care enter the hospital via the emergency department either by an ambulance or as walk–in patients. At the emergency some simple diagnostic tests can be done but if more tests and exams are required, patients are transferred to the diagnostic departments. Emergency patients either can be treated at the emergency and return home or admitted as inpatients for treatments, or return for follow-ups visits to the outpatient clinics. The third way to enter the hospital is the referral by other hospitals or general practitioners requiring diagnostics tests or different therapies or outpatients specialties. The fourth way of entering the hospital is the direct arrival of patients to diagnostic departments, therapy departments, or operating theaters for one- day surgery (elective surgery). Normally these patients are with predetermined appointments and they return home after treatment is finished. In general, the figure illustrates the complexity of the processes associated with the delivery of health care services as well as the higher involvement of different health care professionals in the decision making of providing the health care services. Moreover, actions in one of the departments can change the context for other actions in other departments.

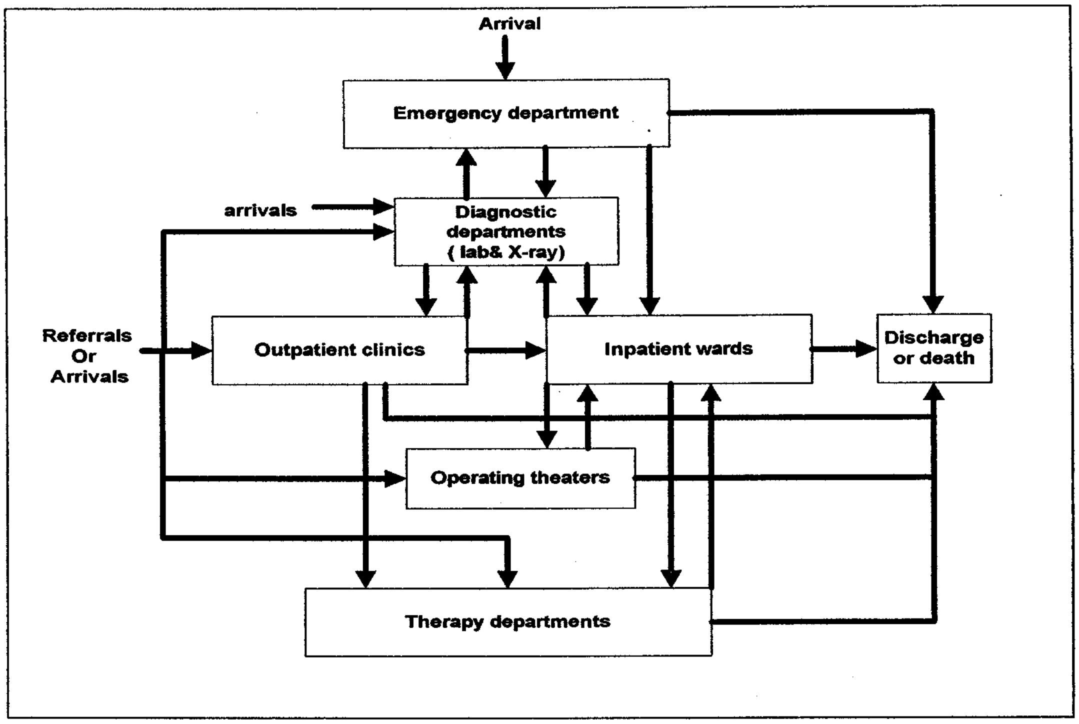


Figure 2.5: Production processes and patient flow.

2.6 Service Quality in Health Care

As efforts by health care organizations to cut costs and restructure health care delivery systems continue, the need for quality measurement intensifies. Quality measurement and management is one of the most important topics in health care today. Health-care systems are mainly composed of patients (receivers) and health-care professionals (producers) in addition to health technology and resources. An important issue in health-care systems is identifying a level of service that is perceived as being satisfactory by the receivers but at the same time lies within the ever-stretched resources of the health-care authorities. In other industries the quality of products and services can easily be measured; however, in health care systems it is very difficult to define what constitutes a quality service, as this is highly dependent on the receivers' perceptions of needs and wants. Adding to the complexity is the existence of multiple decision makers, who in turn may have different perceptions and interests in what constitutes a quality service, especially in a highly politically charged field such as the health care industry. In addition, health-care processes themselves are complex, in terms of levels of interactions between the different variables. There are many reasons why health care quality is important. Providers consider increasing quality in health care to be "the right thing to do". Legnick [26] developed a conceptual model of the consumer contribution to quality, which includes a description of the relationship of perceived quality to satisfaction, and the motivation to change behavior. This is of considerable importance if you consider the relationship between patient satisfaction and compliance with medical treatment plans. Researchers found a positive relationship between the patients' feeling of satisfaction and compliance with respective medical regimes [27] to[29]. Third, as quality improves, expectations increase. According to Moore[30] and Berry[31], as consumers become more quality conscious, service firms not only need to satisfy their expectations, but to exceed them. The consequence of not meeting expectations received some attention. Researchers identify managing the negative reaction that comes from unmet expectations, as a strategic method for ensuring patient satisfaction. Not to do so, is to lose market share and customer loyalty [32] to[33]. Leaders in the health care industry, therefore, need to anticipate patient expectations, and then develop health care services that will exceed them [34]. Shetty [35] maintains that quality can advance profitability by reducing costs and improving an organization's competitive position. Within the health care industry, competitive advantage is best attained through service quality and customer satisfaction in the minds of customers [36]. From the above, we can conclude that, the key factor for attaining a health care organization's goals of operating at low cost and responding to high demand of service quality is effectively managing the producer/ customer relationships which as a result can reshape patient expectations and direct resources to value added activites.

2.6.1 Dimensions of Service Quality

Service quality in health care has many dimensions, some of which are difficult to quantify, but no less essential to its definition. Although quality may be understood in quite different ways and ranked with different priorities between various consumer and health professional groups, these individuals are the key players in the processes of defining and measuring quality and their voices provide an important component to the process. Listening to those dimensions by which the consumer defines the experience and expectations of health care will enable management to incorporate these components into a more comprehensive service quality measurement plan in health care.

Couch [37] suggested that the health care system as a whole has three clinical dimensions as shown in Figure 2.6 .The clinical quality of the goods and services provided which can be measured by the medical outcome of patients. The amenities of care include accessibility of the services when needed and personal caring. Finally, the social quality, which is the degree to which the system obeys a nation's professed social ethic on health care.

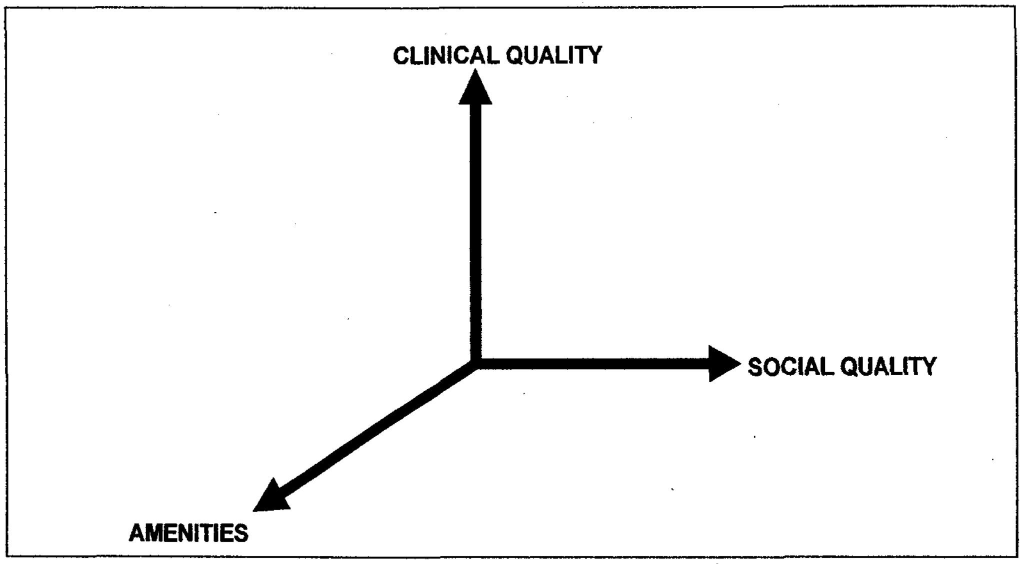


Figure 2.6: The quality-dimensions of a health care system [37].

In an attempt to define service quality Zeithaml et al [38] used 12 focus groups. They concluded that service quality as perceived by customers can be defined as the extent of discrepancy between customer's expectations or desires and their perception. Additionally they defined ten service quality dimensions including: tangibles, reliability, responsiveness, competence, courtesy, credibility, security, access, communication, and understanding of the customers. Similarly, using focus groups consisting of patients, administrators and physicians, Minjoon et al. [39] identified 11 dimensions of health care quality. Eight of these dimensions are tangibles including (physical environment, cleanliness), reliability, responsiveness, competence, courtesy, communication, access and understanding the customer.

In measuring the effect of certain quality indicators on clinician's practices, O'Brien and Edward [40] identified five technical aspects of quality as follows:

- Accessibility;
- Appropriateness;

- Effectiveness,
- Continuity; and
- Efficiency

Donabedian [41] developed seven attributes of healthcare quality including:

- Efficacy (the best result or benchmark for a particular diagnosis);
- Effectiveness (ordinary medicine, or the industry average);
- Efficiency, (a measure of cost, or the least costly of two identically effective treatments);
- Optimality (cost-benefit evaluation, or the point at which further resources do not add benefit);
- Acceptability (adaptation of care to the wishes, expectations and values of patients and their families);
- Legitimacy (the community's view of care); and
- Equity (the principle by which one determines what is just or fair in the distribution of care and its benefits among the members of a population.).

In the United States the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) and the National Committee for Quality Assurance (NCQA) require health care organizations to measure and sustain acceptable patient satisfaction standards. Currently they offer a comprehensive quality review program for hospitals, health plans, home care agencies, laboratories, behavioral health care settings, long term care facilities and ambulatory care settings. Standards focus on twelve general categories, which include patient care, leadership, administration, environmental management, patient rights, and patient/family education.

From the above we can conclude that patient satisfaction or dissatisfaction is determined by a variety of closely linked elements. Moreover, a key role in shaping patient expectations is the intercommunication and collaboration between management, staff, and patients. For the purpose of this research study, four quality elements namely access, convenience, communication and quality of care received are used. These four quality elements with their satisfaction indicators are explored in detail in chapter four.

2.7 Application of Modeling in Health Care Organizations

As it was emphasized in the previous chapter, modeling as a decision support tool has been used in different industries to gain insight in organizational process bottlenecks, improve the quality of services, and resource utilization efficiently. In health care, numerous initiatives have been put in place at both strategic and tactical levels in an attempt to address the problem of escalating health care expenditures and increasing demand that is coupled with limited resources. The applications of modeling as a decision tool in health delivery systems have been growing rapidly over the past decades and can be categorized into four categories [42] as follows:

- Epidemiology, health promotions and disease prevention
- Health care system design
- Health care system operation
- Medical decision making

Modeling is the process of creating an abstraction of a real world system, which reflects the system properties to the desired degree of detail [43]. It is an adequate tool to investigate the system operations, predict system response under different conditions, and allow experimentations. The choice of which modeling technique to use is often based on preference and prior experience. In health care the selection process extends beyond that.

A model can be abstract or concrete, intuitive or formal, graphic or algebraic, hand driven or computerized [42]. Some models are simple and can be solved by analytical methods such as differential equations, probability theory, and algebraic methods. In comparison, in the complex and non linear structured health care system, which has many interrelated and highly varied processes, finding an analytical tool that reflects the complexity, variability, uncertainty, and limited availability of resources has proven to be a hard task. Moreover, the problem of finding such a tool extends beyond that to find a tool that allows the investigator to model the gamut of health care activities quickly and efficiently. To date, the three most frequently used modeling techniques for modeling healthcare systems have been decision trees [44] to [48], Markov chain [44] to [51] and discrete event simulation [44].

2.7.1 Decision Trees Models

Decision Trees are excellent tools for helping in selecting between several courses of action. They provide a highly effective structure within which you can lay out options and investigate the possible outcomes of choosing those options. They also help in forming a balanced picture of the risks and rewards associated with each possible course of action. As a tool for analyzing problems containing risk, uncertainty, and probabilities, decision trees are used for relatively simple systems where events occur over a short period of time. They provide a means of structuring a problem and combing data from various resources. Moreover, they incorporate cost and its affect in the evaluation of alternatives. A decision tree consists of nodes containing estimates of outcome measures connected by probabilistic branches. A major drawback of this technique is the inability to incorporate the variability of cost when evaluating alternatives and quantify the uncertainty in the subjective estimation of branching probabilities [47].

2.7.2 Markov Chain Models

Markov models are useful in health care particularly when modeling clinical problems that involve ongoing risk over time. Events represent the probability that a patient moves from one state to another and are modeled as transition probabilities, i.e. the likelihood that a patient will stay in the current state or move to the next within a given transition period. The movement continues until the patient enters the absorbing state, or state from which he/she cannot exit. The cost of the service or certain medical procedure can be attached to each state patient move to; consequently, total cost can be calculated by multiplying the cost at each state by the duration of time spent at each state and then summing across all states experienced in the model.

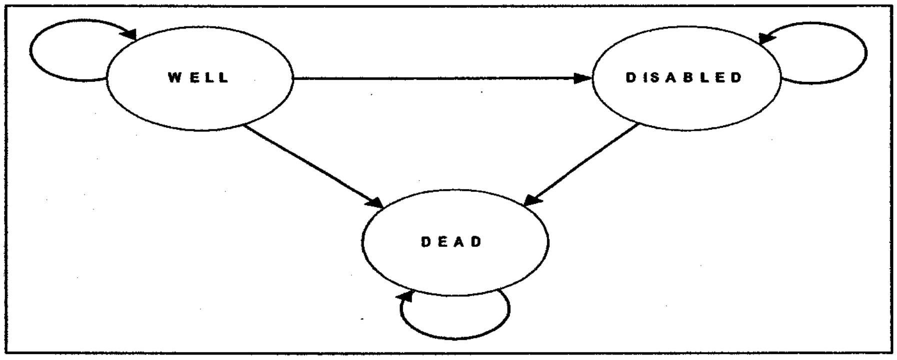


Figure 2.7: Markov state diagram [50]

Figure 2.7 shows a typical Markov chain diagram [50]. One limitation of the Markov chain is that transition probabilities from one state to another are only time dependent and are not influenced by the pathway of patient movement to a particular state. Additionally, a single time period for a transition must be chosen after which the patient is allowed to move to the next health state.

2.7.3 Simulation

Simulation is the imitation of the operation of a real system over time. It involves the generation of an artificial history of a system and draw inferences concerning the operating characteristics of the real system. Simulation modeling is a mathematical model developed with a specific software package for a certain application. "This model usually takes the form of a set of assumptions concerning the operation of the systems. These assumptions are expressed in mathematical, logical and symbolic relationships between entities, or objects of interest of the system" [52]. Simulation models can be classified into six models including: static, dynamic, deterministic, probabilistic, continuous, and discrete as shown in Figure 2.8.

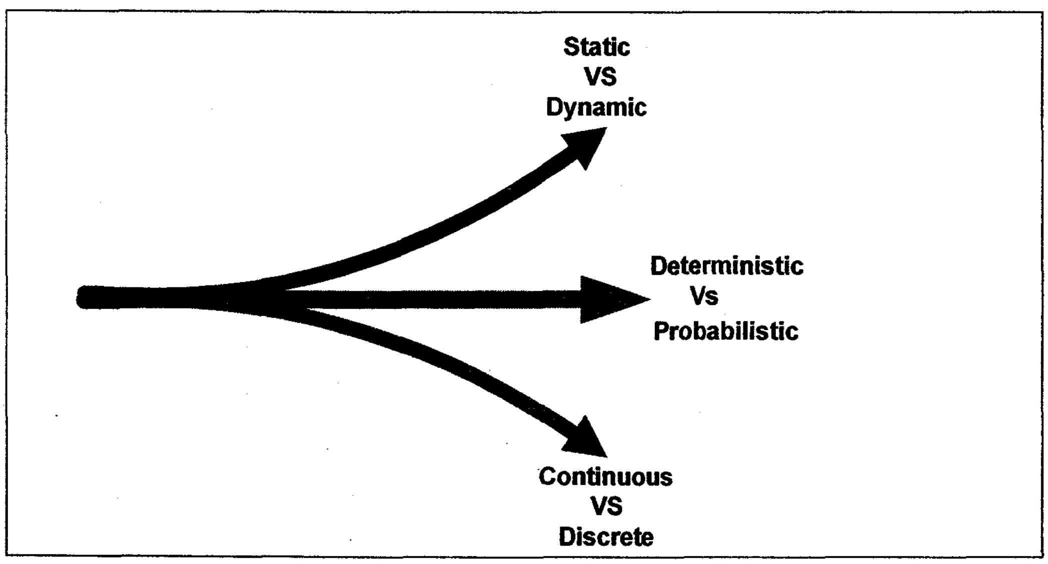


Figure 2.8: Dimensions of simulation.

Deterministic models use constant values for input and output variables where in probabilistic models at least one of the input or output variables is probabilistic. Static models, sometimes called Monte Carlo, are set to run a certain way and do not change regardless of what happens in the model and they represent the system at a particular time. On the other hand, in dynamic models the time varying interactions among variables are taken into account. A continuous model is one in which the state variable(s) change continuously over time. The activity in a continuous model is not broken into unique events and is often expressed in terms of rates and flows. Discrete event simulation model, the approach used in this thesis, is one in which the state variable(s) change only at a discrete set of points in time. One of the main reasons why simulation is becoming a popular technique in investigating health care systems is that simulation may be used for dynamic (rather than static) analysis of the situation, thus presenting health care management with a more realistic picture of the situation [53]. Additionally, when reliable data is not available, discrete event simulation may be used to run a series of different 'what if?' scenarios, allowing the user to understand the interactions of the model parameters, and their effect on the output of interest. This is a great advantage in that it helps users to make a systematic examination of their assumptions rather than be driven by them in building the model and solving the problem.

Various studies with the focus on simulation as an adequate tool for managing health care resources can be found in literature[44] to [52]. A typical simulation process can be shown in Figure 2.9 [52]. All steps mentioned in the figure are used in conducting the simulation study in this research. Banks et al. [52] define step (1), problem formulation, as developing a problem statement. They stress the need for policy makers' involvement in this phase of problem formulation particularly when the problem must be reformulated as the study progresses. Pedgen et al. [54] agree, and expand on the importance of clarifying the issues to be considered; these include hardware design and operational issues. In addition, measures of performance have to be defined before starting the study; Pidd [55] defines this phase as the problem-structuring phase. He suggests that this phase is the attempt to take a "mess" and to extract from it some agreement about the particular problems, which might be amenable to analysis. The second step in Figure 2.9 is setting of objectives and overall project plan. Banks et al. [52] suggest that setting the objectives should be directed toward the questions that the simulation must answer. Additionally, simulation should only be used if an objective can be clearly stated and it is determined that simulation is the most suitable tool for achieving the objective. The third step basically is model conceptualization, which is viewed by Banks et al. [52] as an art. This step involves providing a valid representation of the real system operation. Additionally, the model complexity need not exceed that required to satisfy the objectives of the study. In step four, which is data collection, most authors referenced in this paragraph agree with the importance of data collection and stress the validation of such data.

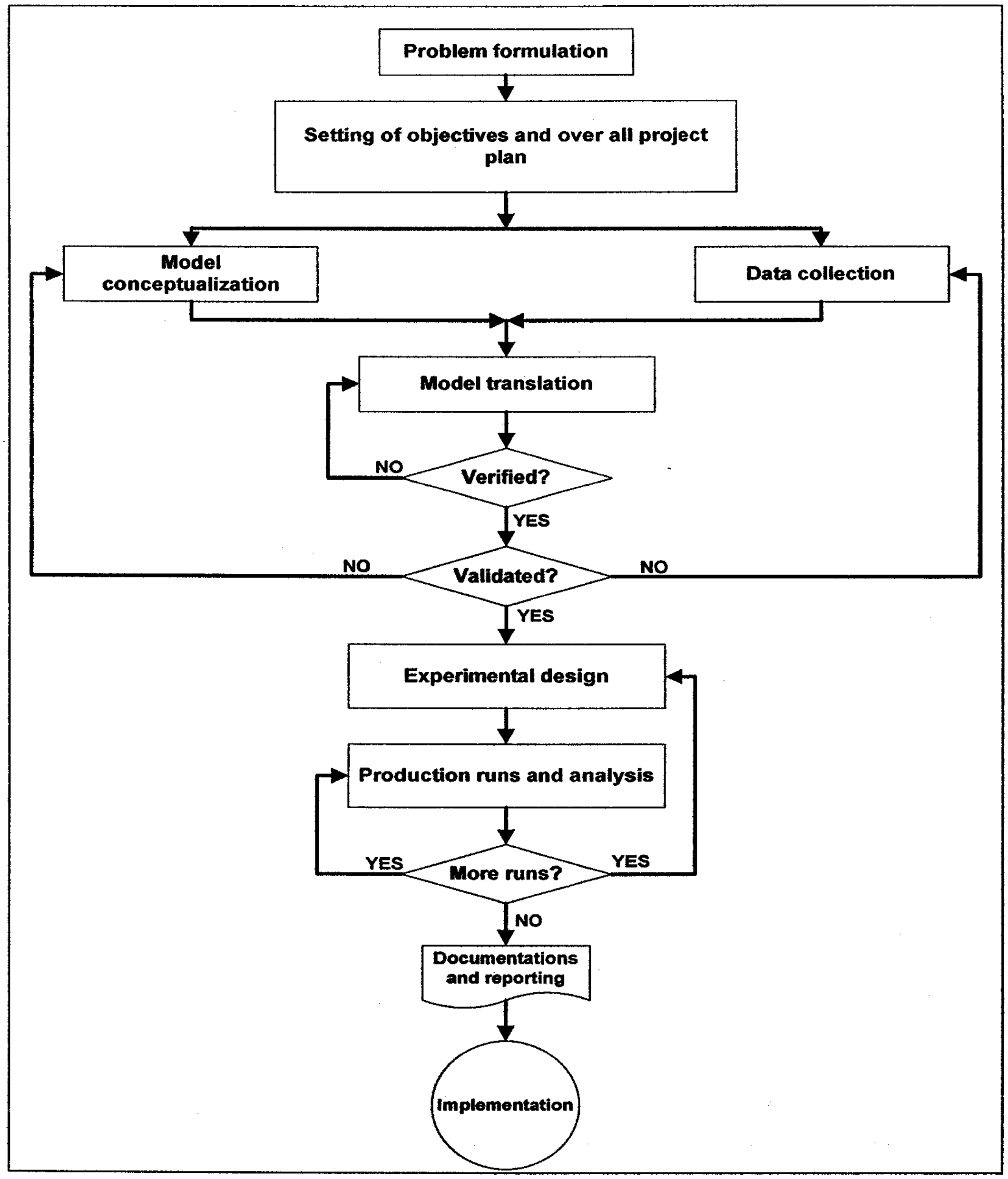


Figure 2.9: Steps in a simulation study [52].

Similarly, Paul and Balmer [56] view data collection as a completely separate process after the development of the conceptual model. Robinson [57] considers the process of data collection as an initial phase in the process of defining the project phases. Law and Kelton [58] suggest data collection should coincide with developing the conceptual

2.8.2 Bed Occupancy and Planning

Maintaining the optimum bed size to meet demands and operating at lower costs is a challenge for most hospitals. Hospital resource management policies have an essential impact on how many beds are needed to meet demands while maintaining effective bed utilization rates. In reviewing the literature for bed occupancy and planning literature simulation modeling was found to be an adequate tool to determine the optimum bed number, eliminate beds in an over bedded hospital; prevent the construction of unnecessary beds, and to overcome bed shortages. Dumas [74] and [75] developed a computer simulation model to address the problem of allocating beds to hospital services by bed type and sex at the Mount Sinai Medical Center in New York City. The model was used to evaluate bed usage policies, admission rules, and the current allocation plans. Moreover, the model was used to study the interrelationships between hospital departments by comparing two bed-planning rules for assigning beds. These were vacancy-basing, which utilizes ranked lists of misplacement possibilities, and home-basing, which prohibits almost all off-service misplacements. As a result, the home basing rule outperformed the vacancy-basing rule in decreasing inpatient days. The overall outcome of the simulation modeling was that hospital beds were reallocated, and admission rules were altered.

Cohen et al. [76] provided a bed-planning model for progressive patient care facilities where the basis for transferring patients from one unit to the other was the change in the patients' conditions. They have shown that the capacity decisions for a given department can affect the utilization and services of the other departments. Harper [77] presented a framework for operational modeling of health care resources such as beds, operating theatres, and workforce needs. The proposed framework incorporated the need for patient model. After data are validated then step (5) is model translation, which is based on the conceptual model. Banks et al. [52] suggest that translating the conceptual model into a computerized model before starting steps (6) and (7), which are conducting the verification and the validation steps. It must be noted that most authors agree on the fact that the validation and verification process should continue throughout the study. Steps (8) through (12) are design of experiments for defining the different alternatives for experimentation, production runs for providing performance data on system designs of interest, output analysis, which consists of statistical techniques for analyzing output from production runs, and implementation of the model's findings.

The use of simulation as an approach to develop new systems or investigate existing systems should be considered when the following situations exist:

- Too expensive, disruptive or difficult to observe the real system;
- Solutions to problems may be too complex to use techniques such as linear programming or other analytical tools (high interdependencies and randomness); and
- Not enough time for system to operate extensively.

Discrete event simulation is particularly appropriate as the interdependencies and randomness (variability) of the system increase. As indicated in the earlier chapter, health care systems are complex systems that require the intervention from different health professionals. Moreover, professionals are highly dependent and this dependency is interconnected so that one action can change the context for other actions. In general, discrete event simulation has been applied extensively developing new health care systems and evaluating existing ones. It provides flexibility; robustness and accuracy. A detailed insight to simulation modeling analysis, developing a simulation study, and simulation advantages will be explored in the next chapters. A literature review of discrete event simulation models and where they have been used for planning and managing resources in health care systems is the focus of the next section.

2.8 Related Health Care Studies

The application of simulation in making managerial decisions and addressing wide-ranging issues in health care organizations is certainly a step forward in improving the quality of health care services and resource efficiency. Examples of many successful applications include several health care areas such as health promotion and disease modeling, resource optimization and allocation, waiting lists and waiting time, patients and staff scheduling, health care policy development, and material handling. Reviewing these applications in modeling and designing health care systems is difficult due to the diversity of application and the nature of the simulation approaches. It was found that there are many simulation models that can describe a variety of health care systems and hospital environments and they are difficult to categorize. For the purpose of this research, I have chosen to present an extensive literature review of various simulation applications that focus only on patient flow and resource allocation in single and multi-facility health care departments including emergency departments, outpatient clinics, inpatient wards, operational theatres, intensive care units, and diagnostic departments. Simulation studies that do not address some aspects of patient flow and resource allocation such as health planning, disease control planning, health policy development, material handling, education, and public health are not presented in this literature review.

Over the past 30 years, several review papers [59] to [61] and tutorials[62] to [67] have been written on the application of simulation modeling in health care delivery systems. England and Roberts [59] gave a well-recognized and comprehensive literature survey in the seventies. They cited 92 computer simulation models representing well over 1200 simulation models and divided them into twenty-one areas including hospital's ambulatory care, health care manpower, health care planning, and other health care models.

Elliott [60] presented four simulation models that described hospital operations. The first model described the operation of an inpatient facility that is experiencing increasing demand for ambulatory surgery. The second model simulated cost per patient based on the expected DRG case mix for a hospital. The third simulation model described the use of simulation in evaluating block scheduling, planning for ambulatory surgery, and for evaluation of a proposed expansion of operating rooms and recovery rooms. The final model described the use of simulation in evaluating new technology in a radiology department. Klien et al. [61] developed a bibliography for the literature of simulation modeling and its application in health care decision-making including the following initiatives: 1) operational decisions such as staffing level, patient scheduling, facilities design and location, 2) medical decision making such as health policy decisions, and 3) epidemiological planning models.

The work presented by Banks and Carson [62] was essential in providing a guideline on the steps required when conducting a health care simulation model. Three actual health care simulation projects were used to illustrate the use of the suggested steps. The study by Lowery [63] gave insight to the challenging issues when conducting simulation modeling in health care including model complexity, preparing input data, model validation and verification, output analysis and simulation promotion. Standridge [64] addressed wide ranging health care issues in the tutorial he presented. These issues included public policy, patient treatment procedures, capital expenditure requirements, and provider operating policies. In addition, technical issues including promoting and accepting the use of simulation in health care delivery systems were discussed. Shannon [65] presented a tutorial for discussing the concept of discrete event simulation modeling and its role in aiding health care decision makers. Moreover, the tutorial included the essential steps in the simulation process as well as the advantages and disadvantages of simulation modeling. Similarly, Centeno [66] provided an introductory overview of discrete simulation modeling in health care with emphasis on the modeling process and an additional list of simulation readings were suggested at the end. Seymour [67] presented a recent review of the modeling techniques in clinical practices. The review focused on the application of bed modeling techniques, potential for such techniques in modeling health care delivery systems, implementation barriers for these techniques, and some measures to be taken to overcome these barriers.

All the previously mentioned articles provided valuable information in assessing the management and clinical practices in health care delivery systems. Moreover, the articles focused on the factors that have the greatest probability of affecting quality improvement in health care and best describe patient flow and resource allocation and the use of simulation modeling in addressing these factors.

In an attempt to review the previous modeling efforts in resource management in health care delivery systems, the focus of the next section will be to present some of the illustrative simulation models, which have been developed, and note their contribution to improve patient flow and the optimal deployment of resources. Moreover, this entire review of simulation modeling in health care is intended to note the effectiveness of this practice in the planning and allocation of resources, investigating current systems, designing new systems, forecasting future demand, and assessing the impact of implementing new resource policies. In doing so, first attempts in modeling hospitals as an entire system that includes a collection of different interacting systems are reviewed. Secondly, the resource planning and allocation in health delivery systems will be discussed. Resources considered include bed allocation and planning, facility design and planning, and staff scheduling and planning. Thirdly, admission control, appointment systems, and patient flow patterns will be explored in detail.

2.8.1 General Hospital Models

An early attempt in using simulation modeling to model the health care system as an entire system to improve patient flow and resource allocation throughout the entire system rather than isolated departments was made by Hindle [68]. The basis of this study was the assumption that the hospital is a collection of interacting queues where patients queue to demand health care services. The main objective was to develop an effective hospital policy to efficiently manage patient flow and hospital resources. Valinsky [69] presented a proposal intended to optimize patient flow throughout an entire hospital from admission to discharge. Barnes et al. [70] described the use of simulation in pre-operation procedures, space and staff utilization, and outpatient studies in two hospitals in the USA. At a hospital in the southeast, simulation was used to evaluate concerns related to staff level, capacity, hours of operation, and patient waiting time. Simulation results provided an adequate tool to examine different potential solutions and select the optimal one in accordance to the hospital objectives. In addition, many problems were solved and substantial money savings were gained in hospital operations. At the Sarasota Memorial Hospital on the west coast of Florida, simulation was used to evaluate a $147 million dollar facility renovation plan. Testing the new facility design through simulation modeling resulted in a tremendous project cost saving, lower operational costs, and improved patient processes. Wong and Au [71] presented a comprehensive and dynamic model for planning health care services in a hospital by simulating envisioned service demand based on patient needs and different hospital policies for providing health services. This dynamic model allowed new health care services policies to be implemented effectively in response to the changing environment of health care demands and technologies by providing an adequate tool for planning staff and facility capacities in a hospital. Gove et al. [72] presented a generalized operational model for patient flow that could be used by any hospital for evaluating various admission and transfer policies. Sepulveda et al. [73] addressed how essential the use of simulation modeling was in evaluating a full service cancer treatment centre. The goal was to analyze patient flow throughout the entire centre, evaluate the impact of alternative floor layouts using different scheduling options, and analyze the resource requirements of the new facility. The model proved to be indispensable in providing the information to reallocate the center's resources and to identify the needed changes inpatient scheduling procedures, which resulted in a 30% increase of patient flow using the same resources.

grouping to capture the variability within the patient population, and the need for a detailed integrated simulation tool for the planning and management of hospital resources. Using the proposed framework, a helpful simulation model in planning and management healthcare resources, PROMPT, was designed. The model enabled the hospital management to understand the consequences of implementing new planning strategies. In another study, Harper and Shahani [78] demonstrated the use of simulation modeling to prove that planning and managing hospital bed capacities based on the simple deterministic spreadsheet calculation does not provide the appropriate information and results in underestimating the true requirements. El-Darzi and Vasilakis [79] demonstrated the use of simulation modeling in explaining a post-Christmas bed crisis at the United Kingdom National Health Service hospitals. The problem was considered as a queuing system and a discrete event simulation was used to evaluate the model numerically. The described model has proved to be essential in understanding the interactions between the different variables of the health care system at the hospital. Furthermore, simulation results have shown that discharges rather than admissions are the main cause of the bed crisis. In another study, El-Darzi et al. [80] showed that simulation could be used to evaluate the length of stay, occupancy, emptiness and bed blocking in a geriatric hospital. In solving the problem of high waiting time in acute states, where some long-stay patients are kept waiting until beds become available for long–stays, the problem was considered as a queuing system where "what–if" analysis is used to determine bed requirements and effective resource utilization. Vassilacopoulos [81] developed a model to meet a predetermined demand for service with consideration to certain operational constraints including admitting emergency patients without delay;

occupancy should not fall below a pre-specified level, and decreased waiting list length. Model results have shown that high occupancy rates can be achieved by using a waiting list and more rationalized admission and discharge procedures, which as a result improve the operating efficiency of inpatient wards. Williams [82] described a model that aided health decision makers on deciding the number of beds needed for a proposed expansion of a hospital intensive care unit (ICU). Based on the modeling results, the decision was made that the ICU size remained unchanged at 11 beds. Similarly, Ridge et al. [83] presented a model for bed capacity planning in an ICU. Simulation results indicated that there was a nonlinear relationship between numbers of beds, mean occupancy level and the number of patients that have to be transferred through lack of bed space. Additionally, they found that there was a heavy trade off between bed occupancy and the number of transfers. Kim et al. [84] used simulation modeling to study various bed reservation schemes in the ICU at a non-typical Hong Kong public hospital. The model proved useful in solving the conflict between surgeons and the ICU physicians and in better utilizing the existing bed capacity to serve patients without incurring additional costs. To study the effect of several parameters, including the number of beds in a hospital, percentage of emergency and elective patients (scheduled patients), and their mean length of stay, Hancock et al. [85] developed a simulation model to predict the correct number of hospital beds given the expected demand. Simulation results have proved that when predicting the number of hospital beds required, all-important parameters and department characteristics must be evaluated. Harris [86] used simulation to compare the variation in the number of beds required in a surgical centre for three physicians under two operating timetables. In the first scenario, each physician was allowed to schedule patients independently, whereas in the second scenario all three physicians were allowed to schedule their patients simultaneously. As a result, the number of beds required was reduced by over 20%. Huang [87] demonstrated the use of simulation modeling to evaluate emergency bed requirements. Bed requirements were simulated on each day of the week based on the actual weekly admission patterns and the empirical length of stay distribution. Simulation results have shown that the model is effective for planning purposes and is easy to apply.

McGuire [88] used simulation modeling to test different operating alternatives with the objective of reducing patient length of stay in emergency departments. His work demonstrated which alternative had the greatest impact on a patient's length of stay. Similarly, Freedman [89] used simulation to study the effect of changing operations on average lengths of stay at two hospitals in the United States. At Washington Adventist Hospital, simulation was used to evaluate an expansion in the number of beds in the ER. As a result, length of stay in the emergency (ER) was reduced by 0.6 hours. At the St. Joseph Hospital, the introduction of a new communication system between nurses and housekeeping staff was simulated. Simulation results have shown a reduction in admission delays from the ER to the hospital, which resulted in reduced average patient lengths of stay. Garcia et al. [90] utilized simulation to assess the effect of implementing a fast track lane on length of stay in the ER. Their study resulted in a 25% time reduction for patients visiting the ER. At St. Luke's Hospital simulation was used to evaluate the impact of a new operational system for the triage process called the triage plus system. The model showed that by implementing the new system a reduction of 40% on the length of stay could be obtained [91]. Jones [92] used simulation modeling to forecast the daily number of occupied beds due to emergency admissions. Simulation was found to be a key factor in solving the two conflicting demands of ensuring that there are enough empty beds to cope with possible emergency admissions and filling empty beds with elective patients.

Reflecting on the above, simulation modeling has been proven to be a valuable tool for health care decision makers in determining the number of beds required to cope with hospital workload and predicting future requirements. It permits experimentation with, and evaluation of bed usage policies and rules, different allocation plans and admission rules.

2.8.3 Facility Design and Planning

In modeling health care systems, simulation has been often used to address problems of facility design and development. The use of computer simulation modeling in health care for planning future expansion, integration, and /or construction of new facilities and departments has greatly enhanced the hospital management's ability to find the most cost effective and efficient solutions to many problems.

In Durham regional hospital in North Carolina, simulation was used to evaluate the impact of introducing an express service area in outpatient departments. Simulation modeling helped provide information on new changes needed before opening the new areas. In addition, it also helped explore modifications to some of the already proposed changes to realize savings of almost $150,000 [93]. Cono and Dawson [94] demonstrated the use of simulation in determining the size of the Gastroenterology division expansion at the University of California Medical Center in San Diego. To solve the problems of increasing volume they built a simulation model with an overall objective of creating a facility that would support the research and patient care activities at the medical centre. The simulation model provided the necessary information for management to understand the behavior of the system under different constraints and circumstances and to select the beneficial configuration to be built in the new GI area. Similarly, to evaluate the initiation of a new construction project for renovating a surgical suit at Brigham Women's Hospital (BWH) to include 32 operating rooms – two less than the current number, Lowery and Davis [95] developed a simulation model using Med Model simulation software. Simulation results showed that the surgical workload could be accommodated in 30 operating rooms if scheduled block time was extended during weekdays and a Saturday block was added. Kuzdrall et al. [96] demonstrated the used of simulation modeling for determining the number of operating and recovery-rooms required under different scheduling strategies in a surgical suite when increasing workload. Simulation was the key in determining the required size of the suite and allowed the experimentation with different scheduling techniques. Meier et al. [97] used simulation in evaluating expansion plans in hospital ambulatory surgery rooms and a freestanding surgical centre. The hospital was considering building 10 ambulatory surgery beds, and opening two operating rooms. Additionally, the freestanding centre had a plan of adding two operating rooms. Simulation results showed that neither of the two plans would be feasible since room capacities at both the hospital and the freestanding centre were adequate to accommodate demands for the next five years. At the West Virginia University Hospital, Currie et al. [98] illustrated the use of simulation as an important decision making tool in evaluating the hospital delivery system. The evaluation included operating room utilization, vertical transportation needs, radiology staffing, and emergency medical operations. Results indicated that a total of 14 operating rooms and 15 recovery beds were required to meet a 20 % increase in demand.

Iskander and Carter [99] developed a simulation model for the same day care unit at a major medical centre to evaluate the system performance under different patient load conditions. The model helped in identifying the facility needs to improve the unit operations and project growth in volume.

Lange [100] discussed the benefits of simulation modeling and how it can speed the planning and designing processes in health care. He presented two cases. At a hospital in Pennsylvania, management decided that simulation would be a good tool to solve the 60 % increase in outpatient care and the decrease in inpatient demand in a five-year period. Simulation was used to evaluate the creation of new units within that hospital that would accommodate all outpatient activities, and allows better utilization of staff and resources. At a hospital in South Carolina, simulation was used to compare two surgical layout designs. Once again, simulation allowed many problems to be solved and aided in selecting the optimal solution. Likewise, Amaldi [101] used simulation modeling in planning and determining the proper size of a new outpatient surgical facility after considering the patient waiting time and facility size as quality measures.

Canteno et al. [102] discussed the use of simulation as a tool in modeling and analyzing a radiology department at Jackson Memorial Hospital after several improvement incentives, such as adding a new neurological operating room and a designated pre holding area for patient comfort were explored.

2.8.4 Staff Scheduling and Planning

The unavailability of sufficient staff and the under utilization of the work force normally results in high patient waiting time and delays. Therefore, staff scheduling and planning is an important factor in achieving greater efficiency in resource use and improving quality of health care services delivered. Simulation modeling has played an essential role in balancing the high patient care demand and labor costs.

Several studies addressing important issues in staff scheduling and planning such as providing cost effective scheduling solutions that can manage a diverse and complex health care workforce, as well as improve the quality of services, have been conducted. Clark and Waring [103] developed a SLAM simulation model for a hospital trauma centre with the objective of improving the scheduling of staff. The simulation approach allowed testing a number of staff scheduling alternatives and as a result, significant improvements in delivering health care services were achieved. Likewise, Draeger [104] developed a simulation model to evaluate alternative nurse staffing in three emergency departments at Bethesda Hospital in the USA. The proposed model allowed testing and evaluation of the staff schedule process before its implementation. Similarly, and in an attempt to evaluate eight scenarios in an emergency department when varying the number of staff, arrival rate, and the diagnostic equipment service time, Lopez and Perez [105] used simulation modeling. They found out that the patient arrival rate should not exceed 12 patients per hour to significantly reduce a patient's length of stay, improve patient throughput, and improve resource utilization. Moreover, they concluded that investments in human resources are more effective rather than new medical equipment. In contrast, other studies by Bodtker et al. [106] and Godolphin et al. [107] found that the availability of new equipment could lead to reducing staff numbers on each shift. At Rashid Hospital in the United Arab Emirates, Badri and Hollingsworth [108] used simulation to evaluate different staff scheduling alternatives and patient demand volumes in the emergency department. In doing so, several scenarios were analyzed and evaluated. Simulation results proved that reducing the number of Emergency doctors by one or more on each staff shift, accompanied with serving only emergency patients, was the most feasible and optimal scenario to be implemented at the emergency department. Evans et al. [109] showed how developing a simulation model could help in assessing different scheduling alternatives for nurses, technicians, and doctors when a performance measure such as the average length of stay of patients is used in the evaluation process. At the University of Virginia Medical Center, Rossetti et al. [110] used simulation to test scheduling alternatives for physicians and analyze their impact on the patient flow in the emergency department. In addition, the model was a valuable tool in identifying the process inefficiencies in the ER.

Hashimoto and Bell [111] conducted a simulation study to gain an understanding of system sensitivity to staffing levels at a general practice outpatient clinic. They used a time and motion study to collect data related to provider times, idle time, patient waiting time, and total time spent in the clinic. Simulation results showed that a decrease of 25 % of the average total time in the clinic can be achieved by restricting the number of physicians in the clinic to four at any time and increasing the number of discharges to two. Swisher and Jacobson [112] developed a discrete event simulation model to assist decision makers in the appropriate staff level and facility size for a two family practice outpatient clinic. Based upon simulation results, optimal staff scheduling decisions and recommendations for the appropriate staff level and facility size were made. Wilt and Goddin [113] used simulation to study the effectiveness of staff levels on patient waiting time in an outpatient clinic. They found simulation to be a powerful tool in achieving the optimal staff size in the clinic.

In an attempt to improve the flow of patients and reduce the time spent in the radiology department of the Midwest Acute Care Hospital, Klafehn [114] used simulation modeling to evaluate several different scenarios for the required number of radiologists at the department. Simulated runs indicated that increasing the current number of radiologists at the department from five to six would result in a reduction of patient lengths of stay. Similarly, Vemuri [115] and Ishimoto et al. [116] proved that simulation is the key factor in achieving the optimal medical staff size and reducing patient waiting time in a pharmacy.

In short, simulation studies have shown that allocation of staff have a significant impact on patient flow, length of stay, and resource utilization in hospitals. Using simulation as an adequate tool, different staffing strategies for several health care facilities and systems can be examined, and as a result, effective decisions on sufficient staff numbers to meet demand can be made.

2.8.5 Admission Control and Appointment Systems

Access to appropriate medical services when needed, reduced patient length of stay and improved resource utilization, lies on putting more emphasis on the procedures that determine how patients' appointments are scheduled and the rules that determine when these appointments can be made. This also may include allocating the optimal medical staff number and sufficient facility size.

Research on patient scheduling started in the 1950s with a work by Bailely [117] where he used a simplified queuing model and static scheduling conditions to examine the appointment system for scheduling ambulatory care patients. Fetter and Thompson [118] conducted another early outpatient simulation study. Their work contained an attempt to analyze the physician utilization rate with respect to patient waiting time, using different input variables including patient load, walk-in rate, appointment scheduling intervals, patient arrival patterns, cancellation or no show rates, physicians service time, physicians break time, and interruptions. Simulation results suggested that if the physicians' appointment capacities are increased by 30% (from 60 % to 90 %) in a fifty-day period, the physicians' idle time decreases by 160 hours. Smith and Warner [119] developed a simulation model for a multiphasic screening procedure for hospital admissions to improve patient throughput and patient waiting times. They analyzed the system by considering two different patient arrival patterns (uniform vs. high variable). Simulation results proved that the uniform arrival pattern could decrease the average patient length of stay by 40% and maximize the total number of patients that can go through the system. Likewise, Kachhal et al. [120] used simulation modeling to demonstrate that cost effective system performance in outpatient clinics can be achieved when demand for outpatient services is evenly distributed. In contrast, alternative scheduling rules have also been investigated. Smith et al. [121] developed a computer simulation model to study the scheduling of patients and resources in one of the family practice units of the University of Alabama. They used a modified wave scheduling scheme to determine the maximum number of patients a physician can see in a three hour session, considering an appointment schedule that minimizes patient waiting time, and determining the required number of nurses and examining rooms to optimize the clinic operations. The principle of this scheme lies in scheduling more patients at the beginning of each hour and less toward the end of the hour. As a result, they proved that using this scheme is superior to the use of the uniform scheduling scheme particularly in reducing patient waiting time and improving accessibility. William et al. [122] showed how a statistical tool that simulates present waiting time conditions and predicts future situations can be used to reduce waiting time in outpatient clinics considerably. Comparing a staggered block scheduling system, where eight patients arrive every half hour, with a single block scheduling system, where sixteen patients arrive simultaneously, simulation results showed that the introduction of the staggered schedule reduces patients' waiting time to about one half of the single scheduling system without any decrease in staff utilization.

Klassen and Rohleder [123] considered more realistic appointment scheduling environments where requests for appointments occur randomly over time, patients may make special time requests, and no show and open emergency slots are also included. In their studies, they analyzed various simple scheduling rules and found that scheduling patients with low standard deviation at the beginning of the appointment session minimizes patients' waiting and physicians' idle time. In a recent study, Rohleder and Klassen [124] addressed the challenges in appointment scheduling in a rolling-horizon environment with variation on demand loads. They considered two scheduling policies including the overload rule, which considers different scheduling methods (overtime, booking) when demand load is high, and the rule delay policy that considers when to implement the overload rules. They tested these scheduling policies with variable demand loads and various performance measures representing both the patient and the provider perspectives. Results showed that defining which measures are most important to management is key in selecting the best choices of overload rules, as rule delay varies substantially by measure. Similarly the papers by HO and Lau [125] and [126] considered a variety of appointment scheduling rules in several environment conditions such as service-time distribution, number of clients per session, and no show probability when selecting scheduling rules. Swisher et al. [127] conducted a study to evaluate the increasing the scheduling of patients in the morning sessions in an outpatient clinic. They concluded that staff overtime and physicians lunch time decreased sharply.

Simulation modeling has been extended to include surgical centre scheduling. An early study conducted by Magerlein and Martin [128] included a literature review on practical use of simulation for scheduling patients in surgical center. Murphy and Sigal [129] demonstrated the use of simulation modeling in investigating different operating room scheduling policies. They examined the surgical block scheduling method where a block of operating room time is reserved for an individual surgeon or a group of surgeons. The surgeon may hold several blocks over a week. These blocks remain constant from week to week which permits more organized scheduling for the O.R. Fitzpatrick et al. [130] employed a computer simulation to improve scheduling in a hospital operating room facility in the USA. Using simulation modeling, three alternative block schedules including fixed, variable, and mixed were compared against the scheduling procedure in use, which used a first come first serve scheduling method. The fixed block schedules the same room(s) and the same number of blocks for a particular case each day of the week. The variable block schedule assigns a different number of blocks to a case type each week under the influence of seasonal fluctuation on demand. The mixed schedule is based on planned cases from the elective list and demand from the waiting list. In this schedule, a fixed block is used for procedures that are time consuming or require specialist set-ups, while using a variable block for all other procedures. Results indicated that variable block scheduling is superior to all scheduling policies in terms of improving the patient throughput, patient waiting time, and the level of service provided.

Manansang and Heim [131] used simulation to investigate patient scheduling for a Mohs-micrographic controlled surgery for a skin cancer treatment facility at the University of Washington to address various scheduling problems. A prototype online simulation scheduling system was designed and constructed. They found that the concept of an on line simulation scheduling system could be effectively used to support scheduling decisions when treating patients.

Simulation was also found to be an important and valuable tool for scheduling and decision-making in hospital inpatient wards. An early attempt in using simulation to study different policies for a large hospital was made by Smith and JR [132] .The goal of their work was to determine better policies for stabilization of admission while maintaining a reasonably full hospital. This goal was accomplished by examining three admission policies: admission based on percentage of discharge rates, discharge rate plus or minus a constant and fixed authorization independent of discharge rates. Results have shown that the last admission policy is more favorable and when implemented, improvements were realized. Another early attempt to use simulation modeling in a hospital inpatient facility for studying admissions and scheduling systems was by Hancock and Walter [133]. They tried to control the variance in occupancy level with the goal of increasing patient flow and enabling the hospital to operate at a reduced cost.

After their first attempt to install the new admission scheduling system, they discovered that the hospital staff rejected the stated objectives of minimizing the variance. They were accustomed to admitting patients on the date of requests 90% of the time, and they refused to schedule elective patients over four and five weeks in advance. In another study, Hancock and Walter [134] used simulation to improve the daily patient loads in 19 ancillary departments by varying average load of daily admission The objectives were to simulate patient flows under a number of scenarios and to determine the average number of procedures that the departments of interest would have to perform on a daily basis. The stated objectives were accomplished by constructing an inpatient load model based on patient flow, an outpatient procedures loading model, and a combined inpatient and outpatient model. The results from the study indicated that implementing a single admission and scheduling policy in all departments could not provide state workload since each department has different health care settings, different patient arrival patterns, and treatments procedures. In a study by Walter [135], several aspects of a queuing system, with particular reference to appointments schemes in radiology departments, were described. He found that improving staff utilization is achievable by segregating patients into inpatient and outpatient sessions with a similar examination time. In addition, overbooking patient appointments resulted in a small increase in staff utilization and substantially increased patient waiting time.

Lowery [136] presented a simulation model to design and improve an admission-scheduling system to control hospital occupancy. The focus of the study was on the technical feasibility of developing a simulation model of patient arrival to discharge. The technical steps for developing such a model were as follows: develop a hospital simulation model, validate the model on two test hospitals, and use the model to design an improved scheduling system. Simulation results have shown that the model can be customized to multiple hospitals. Additionally, the model offers other advantages such as determining the appropriate allocation of beds between different specialties and subspecialties, and providing a mechanism for structuring the hospital's planning process.

In conclusion, admission control and appointment systems have a significant impact on resource allocation and increasing staff utilization rates. The studies reviewed here suggest that simulation modeling is a powerful tool that can be used effectively in investigating several admission rules and policies prior to implementing them which can result in substantial improvement on patient throughput and waiting time.

2.8.6 Patient Flow Patterns

Examining the daily bed requirements arising from the flow of emergency admissions and identifying the implication, fluctuation and unpredictable demands for emergency admission is a challenge for most hospitals' management. Although patient arrivals are highly unpredictable, increasing staff utilization and minimizing patient waiting time is possible by investigating patient routing and flow through the hospital system.

Garcia et al. [90] studied the flow of patients in the emergency department at Mercy Hospital and decided to model it with and without a fast track lane that is dedicated to serving low priority patients. The simulation study revealed that using a fast track lane that uses a minimal amount of resources, reduces patient waiting time by almost 25%. Similarly, in another simulation study of the emergency department at the University of Louisville Hospital, Kraitsik and Bossmeyer [137] used a fast track lane and a "stat" lab for processing high volume tests to improve patient flow through the emergency department. Likewise, in another attempt to reduce patient length of stay and improve patient flow in the emergency department, Kirtland et al. [138] examined 11 different alternatives and selected the optimal three alternatives that reduced patient turnaround by an average of 38 minutes. The top three alternatives were using a fast track lane for non-urgent patients, staging of patients to the next available treatment room, and the use of point -of- care when processing lab tests.

McGuire [88] used Med Model simulation software at an emergency service department in a Sun Alliance Health hospital to test alternatives and choose significant solution(s) for reducing patients' length of stay in the emergency department. Proposed solutions included adding a registration clerk during the peak working hours of the day, extending the hours of operation of the fast-track lane and pediatric clinic, and adding a holding area for waiting patients. Additionally, results showed that improving the fast track area could be achieved by using physicians instead of residents in this area. Blake and Carter [139] used discrete event simulation modeling to investigate patient waiting time at the emergency department in the Children's Hospital of Western Ontario. Results indicated that patient waiting time is highly affected by staff shortages and the amounts of time physicians were required to spend engaged in teaching medical residents. Based on the findings, the hospital implemented a fast track facility for treating patients with minor injuries and has increased the number of physicians in the emergency department.

2.9 Summary of Literature Review

Studies reported in this literature revealed that the complexity and different interactions within the health care delivery system have given emphasis to the modeling of individual subsystems within hospitals. Issues of high concern and challenges such as patient scheduling, patient throughput, patient waiting time, staff and facility utilization, resource planning and allocation were the theme of these studies. Although modeling efforts have been extended to include several aspects of health care delivery systems and their environment, the majority of research has been directed towards the area of patient flow and resource allocation in specific departments. Recommendations for improvements from such studies lack an overall prospective since optimal solution(s) lack the ability to be generalized. Another limitation of the reviewed studies is that they do not give much attention to the involvement of patients and health care professionals in the stage of problem formulation. The involvement of both patients and health care professionals throughout the modeling process is a key factor in understanding the real problems and enhancing the communication and collaboration among all parties. Furthermore, none of the reviewed studies in this chapter provide a measure to evaluate staff and end-user perception on the effectiveness of the recommended improvements or new policies after implementing them. Moreover, the modeling processes in the reviewed studies are based on pre-determined objectives and requirements, which make it less adaptive to changes. Lastly, the literature review presented in this chapter has shown that the use of discrete event simulation modeling over other mathematical modeling techniques, such as linear programming and stochastic processes, is more applicable when modeling health care systems. In addition, for simulation to reach its potential as an adequate tool for modeling health care systems, such an approach is effective in overcoming implementation barriers by addressing the real problems and concerns that have the most effect in delivering quality of health care services at a lower cost. Reflecting on the above, an alternative approach to solving these limitations, with a main theme of enhancing the involvement of both patients and health professionals through constructing an iterative dynamic model, is the focus of this thesis.

Chapter 3

Theory and Model Description

3.1 Introduction

This chapter presents a new improvement framework using simulation as a decision support technique to efficiently manage and allocate resources in service organizations. When organizational problems such as resource planning and management are studied in an effort to find the optimal strategies and practices, it is important to view these problems from several different perspectives. Some examples include workforce, management, end-users of the services, and the analyst. In the improvement approach presented, simulation is not only regarded as an adequate tool for deriving solutions to certain problems, but also as an active key driver in understanding the system operational aspects, concerns, and problems and enhancing communication among the problem owners. The proposed improvement framework focuses on the importance of involving the problem owners in the early stages of problem definition and objective development. Another important consideration in the new proposed framework is directed toward the need for gaining an understanding of how the service delivery system works and identifying redundant and non-value added activities incorporated in the delivery system as a result of the current resource management practices and strategies. This can be accomplished by identifying the factors that have the greatest probability of solving the problem and affecting the quality of service provided. In section 3.2 of this chapter a general description of the four stages incorporated in the proposed improvement framework is given. Next, in section 3.3 the analogy to input-output of the proposed improvement framework is explored in detail. Then, the problem owners' classification and defining characteristics are presented in section 3.4. In sections 3.5 through 3.10 the modeling processes incorporated in each stages of the proposed improvement framework are described in detail. This includes internal and external assessments, process analysis, PDSA cycle, communication and feedback, simulation process, and implementation and post evaluation respectively. Next, in section 3.11, background information and a description of an outpatient clinic, in which the case study was performed, are given. Logic and key components of the simulation modeling process are explored in detail in section 3.12. Section 3.13 provides an overview of software used for conducting this research and its unique characteristics. In section 3.14, the justification for using simulation as an adequate tool for modeling health care delivery systems and main reasons for considering Med Model software for modeling purposes are addressed. The last part of this chapter, section 3.15, summarizes and identifies the defining aspects of the proposed improvement framework.

3.2 General Model Description

As emphasized in the problem formulation section, the involvement of stakeholders (management, workforce, end-users, and analyst) in the early stages of model development is the key factor in overcoming any conflicting objectives and buy-in challenges. Therefore, the main concept of this new proposed improvement framework is related to enhancing communication, collaboration, and understanding among the problem owners in order to develop a valid model's requirements and objectives. Moreover, the new proposed improvement framework gives an insight to the importance of the data collection processes and problem definition in the early stages of the modeling process. Reflecting on the above, simulation is used here as tool for modeling service delivery systems in an attempt to solve well-defined problems related to resource planning and allocation in service organizations, where problems may not easily solved analytically due to the complexity of the service delivery system and the involvement of different decision makers with diverse interests and backgrounds.

As it is shown in Figure 3.1 the new proposed improvement framework consists of four stages:

I. Stage (1) - internal and external assessment.

II. Stage (2) - the plan, do, study, and act (PDSA) cycle and process analysis,

III. Stage (3) - the modeling process; and

IV. Stage (4) - implementation and post evaluation.

From the figure, the main factors that make up the new modeling approach are:

1) determine problems and concerns represented by the two processes in stage one,

2) continue data improvement (PDSA) cycle

3) process analysis which defines the operational aspects of the delivery systems that best describe stakeholders concerns;

4) modeling processes which include building conceptual models, building time base models, and experimentations;

5) communication, which is related to the mutual relationships and collaboration between the problem owners, analyst, and the model itself through the exchange of information and feedback; and

6) implementation and post evaluation of the new alternatives or policies.

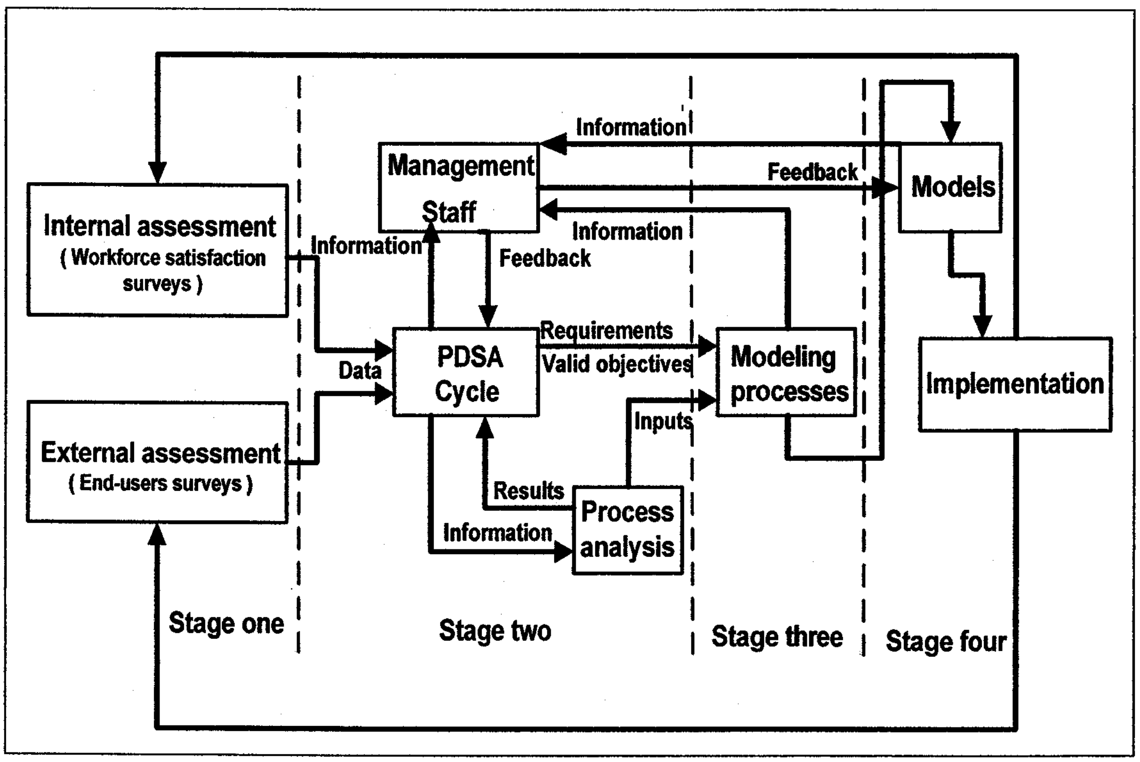


Figure 3.1: New proposed improvement framework.

The modeling process is a close loop iterative process rather than step-based process. This makes it highly adaptive to changes at all stages. In return, the iterative process assures that the model objectives and requirements represent stakeholders concerns. This means that, as the stakeholders understanding is continuously improved through communication and collaboration through the (PDSA) cycle, the objectives are defined. The iterative process is continued until the stakeholders concerns are incorporated in the model requirements and objectives. The underlying principle of the proposed improvement framework is based on participation and involvement in the modeling process at the early stages in an iterative manner. Moreover, the iterative process is mainly governed by the stakeholders rather than by pre-specified requirements and objectives, as is the case in a step-based process, and is highly adaptive to changing requirements and objectives. Consequently, in stages (1) and (2) all decisions made regarding determining the model's requirements and valid objectives are not final and can be changed at anytime to fit the stakeholders' needs and concerns.

3.3 Analogy to an Input – Output Model

As it is illustrated in Figure 3.1 the initial step in the proposed approach is that the stakeholders should identify a set of problems and concerns in the current service delivery system via the use of three methods. The first method is an internal assessment of the delivery system which includes identifying problems and concerns of the workforce related to system operations, work load, availability of certain resources, and work environment. The second method is through the use of external assessments where end-users of the services provide their concerns, problems, perceptions and expectations of the services delivered. The third method for identifying the major system problems and inefficiencies is through process analysis. This method provides extensive detailed process information such as resource schedules, redundant and non-value added activities, activity durations, and activities necessary for achieving the end product or providing the service. The output of the three methods is fed into the Plan Do Study and Act (PDSA) cycle where the iterative process starts for continuous data improvement. In this iterative process, management and staff are allowed higher authority over the analyst and model to identify in their view what are the real problem and concerns about the service delivery system. This greater involvement of stakeholders in the modeling process can help facilitate the understanding process. It also enables the stakeholders to more fully appreciate the findings from the model and as a result overcome any implementation obstacles. With a detailed understanding of how the system operates, objectives and requirements can be developed. The developed objectives and requirements should serve as the basis for the simulation modeling process, which is the last step in the proposed improvement approach. In summary, simulation results are communicated to stakeholders for their feedback and if there are no further analyses to be conducted, simulation results are used to make recommendations for improvements in the actual service system. Note that the solid arrows in the proposed improvement framework represent the direction of the modeling process, exchange of information, feedback, inputs, and outputs among the stakeholders or between the analyst and the model. To help explain the new proposed framework, a concrete case will be discussed throughout the next chapters where it will be used and implemented to evaluate the health care delivery system at Zayed hospital in the United Arab Emirates. Moreover, the four stages of the proposed improvement approach will be explored in detail in the following sections of this chapter.

3.4 Stakeholders Classification

As indicated earlier, a unique aspect for the proposed improvement framework is the fact that problem owners are involved in the modeling process from the initial stages to the end. In the proposed improvement approach, stakeholders are defined as those who are most interested in finding solutions to inefficiencies and bottlenecks within the service delivery system. Classifying stakeholders helps in fitting them to their roles in the four stages of the new proposed improvement approach. The interaction and collaboration between the stakeholders, analyst and the model positively contributes to better decision making in defining areas of improvements and bottlenecks in the service delivery system. For the purpose of this thesis, 'stakeholders' are categorized as management, workforce, end-users of the services, and the analyst. The main purpose of classifying stakeholders is to facilitate the data collection process by identifying appropriate data sources, their relevancy, reliability and accessibility. Management should have a high interest in identifying better ways for quality of service at lower operational costs. Additionally, management's understanding of the existing problem in the delivery system is important in identifying areas for improvement and facilitating the implementation of new changes. Similarly, the workforce should share the same interest in solving the problem. They represent the source for the detailed knowledge of the delivery system and its operational aspects. Moreover, the workforce is the actual user of the model whose feedback and input are in setting model objectives and requirements solving the problem. Their understanding about the system inefficiencies and bottlenecks can help shape their perceptions and expectations. Lastly, the analyst is a person(s) who is interested in investigating the delivery system in order to find the optimal solution to solve a well-determined problem. The analyst's tasks can be summarized as follows:

- Determine the data requirements for the modeling process;
- Collect data relevant to problem solving and system improvements;
- Communicate data and information to management, workforce, and end-users;
- Develop final requirements and valid objectives for the modeling process based on the inputs from management, workforce and end-users; and
- Conduct the modeling process and report results including recommendations for system improvements.

The defining characteristics of stakeholders in the proposed improvement framework are presented in Table 3.1.

Table 3.1: Stakeholders classification and characteristics.

Stakeholders	Characteristics
Management	- High interest in solving the problem, operational cost, provide quality of services - General view of the delivery system - Strategic decision makers - High interest in the success of the modeling process
Workforce	- High interest in solving the problem - More experience with the operational aspects of the delivery systems - Manage and conduct day-to day system activities - Actual users of the delivery system - High concern about work environment
End-users	- High interest in solving the problem - High expectations of the delivery system - Continuously demanding quality of services - Help in shaping satisfaction indictors and level of services
Analyst	- High interest in solving the problems - A communication link between the model and management workforce, and end users - Directly work with the model - Manipulate and process model's information and data

3.5 Internal and External Assessments

As indicated in the previous chapter, evaluating the quality of services delivered is a multidimensional process that requires consideration of hundreds of variables. The underlying is to focus on the factors that have the greatest probability for making significant improvement; and best describe the workforce and end–users satisfaction and perceptions. These include the current management practices at the service organization, resource utilization, and end-user and employee satisfaction. The results of this evaluation process will then be used as the basis for understanding the current problem in the delivery processes at the organization and defining valid objectives and requirements for the simulation modeling process. Moreover, the resulting dissatisfaction determinants from the internal and external assessments can be used to establish the need and basis for the modeling process.

3.5.1 Internal Assessment

Any organization conducts employee surveys as part of the organization's ongoing satisfaction and improvement measurement practices. Conducting a work satisfaction survey serves to gauge employee opinion on workplace issues, workload, availability of certain resources, work environment, and which attitudes are important to the modeling process. There are several tools to conduct workforce assessment and satisfaction. The most commonly used tool is a questionnaire containing issues important for the employee satisfaction metric [142]. The information gathered from the questionnaire is used to identify statistical trends in certain groups and to provide management and the analyst with platforms for action in areas identified as challenges and problematic.

3.5.2 External Assessment

A greater challenge in today's changing environment is the constantly escalating end-user expectations. This escalating expectation, as emphasized in an earlier chapter, is further complicated by a growing demand for service quality above what has been seen previously. End-user satisfaction is a fundamental requirement for the financial and operational success of any service organization. End-user dictates what is, and what is not acceptable or exceptional. Although end-users satisfaction – the process of meeting or exceeding end-user expectations–is an attitude, it serves as an antecedent to end-user loyalty. Another importance of end-user satisfaction is that it gives an insight to the current mechanisms of recording and tracking end-user complaints related to the service delivery system and services provided. End-user satisfaction or dissatisfaction is determined by a variety of closely linked elements that, when combined, drive each end-user's perception of the overall service quality and value received. There are a variety of methods that can be used to directly or indirectly measure end-user perceptions and satisfaction. These include [140] :

- Opened-ended questionnaire which is a valuable source of qualitative information;
- Objective survey questionnaire is considered the best instrument for obtaining quantifiable response data;
- Lay advisory panel, which consists of four or five end-users who are relatively articulate and representative of the demographics of the organization's population;
- End-user focus group, which consists of a group of end-users who are representative of the entire organization and are led through a group discussion that is structured to evoke suggestions and perceptions,
- Computer-based end-user input where organizations have Internet web sites available for them to voice their concerns and complaints; and
- Complaint analysis, which involves various efforts to collect, record, and analyze end-user complaints.

The mechanism selected for measuring end-user satisfaction should be an accurate representation of the satisfaction elements and their indicators. In addition, ensuring that responses are based on multiple experiences rather than a single event is very important for collecting reliable data. The overall objectives of the end-user satisfaction survey can be summarized as follows:

- To develop a means of measuring current end-user satisfaction that is service centered, and department and provider specific;
- To identify 'dissatisfaction areas' for elimination and/or improvement;
- To identify strong satisfaction determinants. These determinants should be used to establish the need and basis for the modeling process. In addition, they will give an insight into the current capabilities in managing the service delivery system at the organization; and
- To establish end-user satisfaction performance standards.

3.6 Process Analysis

Gaining a detailed understanding of the service delivery processes is an essential factor towards solving the problem and identifying areas for improvement. With clearly defined problem, a detailed study of the service system can begin. This step can actually be viewed as developing a conceptual model on which the simulation model will be based. The initial step in defining the service system is gathering and validating system information. This step is a goal-oriented step with a focus on data that will achieve the predetermined requirements and objectives. To help organize the system data-gathering process the following steps can be used:

1) **Determine data requirements.** As described above, gathering system data is directed by the scope and level of detail required to achieve the predetermined requirements and objectives. The initial focus should be on defining the overall process flow going from general to specific and adding more detailed information gradually as it becomes available;

2) **Using appropriate data sources**. In deciding whether to use a particular source of data, it is important to consider the relevancy, reliability and accessibility of the source. If the information that a particular resource can provide is irrelevant for the model being defined, then that source should not be consulted;
3) **Making assumptions** where necessary. If accurate information is lacking or unreliable, assumptions can be made. The point here is that these assumptions must be agreed upon between the problem owners and the analyst;
4) **Converting data into useful form.** Usually, some analysis and conversion needs to be performed for data to be useful as input parameters for the simulation. An example is random phenomena that must be fitted to some standard, theoretical form such as normal or exponential distribution, or be inputted as a frequency distribution; and
5) **Document, validate, and approve all data.** When it is felt that all relevant data information has been gathered and organized into suitable form, documenting the data in the form of data tables, relational diagrams and list of assumptions should commence. Then this documented information is presented to problem owners for validation and approval;

Reflecting on the above process analysis - where the current delivery system is defined- is important to accurately determine the major factors that contribute to system inefficiencies in providing services. In addition to the importance of the process analysis in providing an insight of the operational aspects of the delivery systems, one can summarize its role in the proposed improvement framework as follows:

- It is a structured way to show who is doing what, when, how and where in the process, from beginning to end;

- Shows the dependencies of activities in the delivery system;
- Provides detailed process information, such as business rules, assumptions, resources available for use, resource schedules, sequence of activities and their duration;
- Identifies the value-added activities that are necessary for achieving the end objectives and; and non-value activities in the system;
- Helps develop key performance indicators and service levels;
- Provides input for training and other deliverables, such as job designs and detailed task documents; and
- Identifies gaps between current capabilities and desired objectives.

Lastly, defining the system (process modeling) is comprised of:

1. A process map where flow charting software (i.e., Visio – the one used in this research) with customized templates can be used to create process flowchart diagrams based on system observations and input from problem owners; and
2. Related process documents. Where all the data relevant diagrams are documented using customized software (i.e., access database).

3.7 Plan, Do, Study, and Act Cycle

The Shewart/Deming PDSA cycle of improvement provides an excellent framework for process improvement and outcomes. It consists of four stages (Plan-Do-Study-Act) as shown in Figure 3.2 [141]. This continuous improvement process is carried out in the sequence shown in the figure.

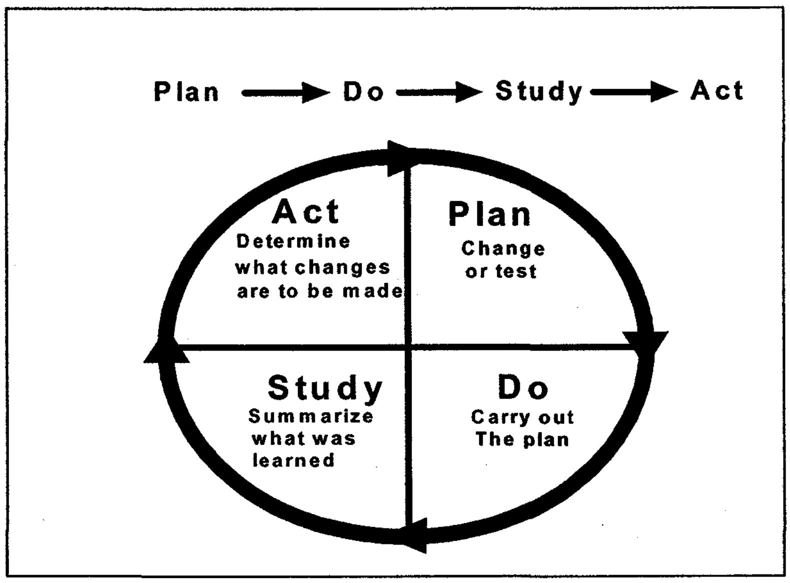


Figure 3.2: (PDSA) cycle [141].

The use of this powerful tool in the proposed modeling approach is mainly to refine the data and information through several PDSA cycles. This improvement process is conducted by the analyst and is continued until it is felt that an acceptable understanding of the system's problems and bottlenecks has been achieved. The same is applicable for process analysis where the delivery system processes have to be defined. The improvement process is continued until reliable data that best describe the operational aspects of the delivery system and represent workforce concerns and problems is achieved.

PLAN- This step includes collecting and predicting change in data. It also includes setting up a strategy for collecting the data such as: who will collect the data; when and where it is going to be collected; and looking at the evidence for change to plan the change process.

DO- In this stage the predicted change is carried out and tested. Additionally the data collection process and initial data analysis starts at this stage.

STUDY- At this stage a complete data analysis is conducted and the effectiveness of the data is tested in small scale under controlled circumstances. Then data are compared with predictions and results are summarized.

ACT- At this last stage of the PDSA cycle actions are taken to standardize the processes and activities that produced the desirable data before the next test cycle, and the implementation process of change starts.

Generally, it is important that the analyst works with other stakeholders through these stages and reiterates that the goal is not perfection but rather is learning and improvement.

3.8 Communication

As emphasized earlier, one of the main objectives of this new proposed improvement framework is to enhance communication and collaboration between stakeholders, the analyst, and the model. It is related to the mutual relationships among the different players (management, workforce, analyst) and the model itself. Moreover, communication is an important issue in the proposed improvement approach. Via satisfaction surveys and interviews, stakeholders can feed their input directly to the modeling process. In the modeling process, promoting communication and collaboration among stakeholders is one major objective. With higher consideration given to the stakeholders' involvement in model building, the main principle of the proposed approach is that modeling process is actually a communication link between the model and the stakeholders. As a result, this helps enhance the collaboration between the different stakeholders, each with their different background, experience, needs and perceptions.

In the proposed modeling approach, communication is divided into three categories; stakeholders to model, stakeholders to analyst, and analyst to model communication. The three categories are defined below.

(1) Stakeholders to model: This includes retrieving and feeding data from and into the model. The model is considered as a destination when requirements, objectives, and feedback are fed into the model, or it could be considered as a source of data when results such as simulation results are retrieved from the model.

(2) Stakeholders to analyst: This represents the mutual communication between the analyst and the stakeholders in the early stages of problem definition and objectives development. This includes both qualitative data as a result of the end-user and workforce surveys and quantitative data as results of defining the operational aspects of the service delivery system. This type of communication is not directed to the model. The source is the stakeholders and the destination is the analyst. The model here is used as a means of communication only but not a source or a destination.

(3) Analyst to model. This communication is between the analyst and the model where the analyst conducts and manipulates the information, manages the simulation process, and alters model inputs. The model here is a destination and all the data is a quantitative data.

Data in the proposed improvement approach includes any information that might be fed into the model or retrieved from the model. Feedback is comments in the form of opinions about the model by the stakeholders in an attempt to provide useful information for improvement decisions. Information here can be divided into two categories: quantifiable and non-quantifiable information. Quantifiable information includes information such as simulation inputs and simulation results. This information purposefully gathered as a result of the evaluative studies and model experimentations. On the other hand, the main principle for the non-quantifiable information is that it is not restricted to any modeling stage and can be retrieved from the model, end-users, workforce, and management. This type of information is used to understand the behavior of the service delivery system under study.

3.9 Simulation Process

Once internal and external assessment data has been analyzed and sufficient information has been compiled to define the delivery system operational aspects, the model building activity can begin. In this proposed improvement approach, the model building process is considered as a valid representation of the defined system operations, problems and concerns of the stakeholders. Building the simulation model here means preparing simulation specifications, progressive refinement, incremental expansion, model verification, and model validation, conducting experiments, analyzing the output, and reporting results.

The modeling process starts by setting requirements and valid objectives for developing the model based on the results of the end-users and workforce surveys and process analysis. After incorporating results in the model, a progressive refinement strategy, where details are added to the model in stages rather than all at once, starts. This strategy is used based on feedback from problem owners.

The following steps are generally taken in the simulation modeling process. These steps are now presented.

(1) Preparing simulation specifications.

After incorporating the problems owners concerns and needs in the model objectives and requirements, simulation input data can be specified. Defining a specification for the simulation model is essential. It guides the modeling process and helps shape problem owners expectations by clarifying to them exactly what the simulation model will include or exclude. In the proposed improvement framework, specifications represent refined requirements and needs from the problem owners. Moreover, requirements and objectives are not fixed and they change based on a refined understanding of the problem. Consequently, getting to the final requirements and objectives may require a number of iterations through the (PDSA) cycle, as shown in the proposed improvement framework. The continuous data improvement process continues until the problem owners achieve an acceptable understanding of the problem and agree with the proposed requirements and valid objectives. Aspects of the simulation modeling to be contained in the specification include scope, level of detail, degree of accuracy, type of experimentation, and form of results.

(2) Progressive refinement.

Progressive refinement is concerned with all the activities that add new or alter existing features for either the conceptual or the time-based model (e.g., structure, inputs and outputs). This is used for developing the model or modifying it, based on the new needs and thoughts from the problem owners. In this strategy, details are added to the model in stages rather than all at once. It also a validation measure for the analyst. This process is incorporated in the (PDSA) cycle.

(3) Model verification

Once the model is developed using the selected software tool, it must generally be debugged to ensure that it works correctly. The process of demonstrating that a model works as intended is referred to in literature as model verification [52] to [58]. Most simulation languages provide a trace capability in the form of audit trails, screen messages, graphical animation, or a combination of all these features for the purpose of model verification.

(4) Model validation

Model validation is basically the process of determining the degree to which the model corresponds to the real system, or at least accurately represents the model specification document. It is an inductive process through which the analyst draws conclusions about the accuracy of the model based on the evidence available. Gathering evidence to determine model validity is largely accomplished by examining the model structure (i.e. the algorithm and relationships) to see how closely it corresponds to the actual system definition. Graphic animation can be used effectively as a validation tool for model validation. Moreover, output results should be analyzed to see if the results appear reasonable when compared to the actual system. In general, validating a model is the process of substantiating that the model is sufficiently accurate for the intended application.

(5) Conducting experiments

In a simulation experiment, input variables and parameters defining the model are manipulated or varied. The effect of this manipulation on other dependent or performance measures are measured and correlated. This process is mainly conducted by the analyst under the stakeholders' direct authorization. Model experimentation represents a change in the model output that accounts for stakeholders' needs and problems. Experimentation in general is about the utilization of "what-if" capabilities, identification of the significant decision variables, and output data collection. The main goal of conducting an experiment is not just to find out how well a particular system operates but also to gain an insight as to how the delivery system can be improved.

(6) Analyzing the output

Output analyses deal with drawing inferences about the actual system based on the output results. Its purpose is to predict the performance of a system or to compare the performance of alternative system designs. Due to the probabilistic nature of the inputs in simulation, any sound conclusions related to system improvement cannot be drawn before proper statistical analysis is conducted. The purpose of this statistical analysis is to acquire some assurance that the experiment performance measures estimates are sufficiently precise for the proposed model application and objectives.

(7) Reporting results

This is the last step in the simulation modeling process where recommendations for current system improvements based on the results from the simulation model are made. Recommendations should be supported by evidence and clearly presented so that an informed decision can be made. Obtaining feedback on the output results from the problem owners as soon as possible is extremely important for the feasibility of new changes to the current system. This also reduces the probability of problem owners changing their requirements and objectives. Documentation of all data used in developing the model and conducting experiments should be included as part of the simulation report.

3.10 Implementation and Post-Evaluation

To ensure that the new model(s) can improve the system inefficiencies and bottlenecks, modeling results must be implemented, and then system performance must be monitored and evaluated under the new operating conditions and policies. Implementation, in the proposed modeling approach, is the process where the effectiveness and efficiency of the model is measured. The implemented new resource management strategies should provide a new prospective on the relationship between the available resource and the quality of services provided by the health care delivery system. Workforce involvement at the early stages of model development should help overcome any implementation resistance.

On the other hand, the post evaluation process refers to the performance evaluation of the service delivery system under the new resource management policies. The purpose of this post evaluation process is to collect data related to delivery system performance at a sufficient point of time after the implementation process to compare and validate the initial model requirements, workforce and end-users satisfaction, and the quality of services provided. This includes a comprehensive assessment of the extent to which the modeling process objectives have been achieved. Moreover, the impacts of implementing the new model(s) on system performance and operations are assessed on the basis of before and after implementation. Furthermore, the evaluation process is intended to assess the effectiveness of the processes and methods incorporated in the proposed modeling approach for the purpose of ongoing continuous data collection improvement. Data for post-evaluation is collected using end users and workforce surveys. These surveys are used to determine the extent to which the new model(s) satisfied the end-users and workforce requirements and expectations. Another important aspect of this process is the timing of the post evaluation process. Post evaluation needs to be undertaken when the implementation process is fully completed and normal operating conditions are experienced. Specifying the post evaluation period and time after the implementation process is essential in maintaining the balance between realizing changes in system performance and being close to the deployment process to have relevance and adequate data. In our case, it was suggested that a period of 6 months to one year is adequate to realize changes and collected relevant data that would allow us to measure the effectiveness and efficiency of the new model(s). Lastly, by comparing the satisfaction surveys results before and after implementation, the model(s) then can be categorized as generally successful, partly successful, or unsuccessful.

To conclude, post evaluation should provide insight into important issues affecting the implementation performance, system operations, and the long-term success and sustainability of the model. Major consideration in this step is directed toward identifying key issues to improve the efficiency and effectiveness of the system, lower operational cost, and draw meaningful lessons of experience to improve future modeling process efforts. This process is conducted on the basis of three main characteristics: effectiveness, significance, and efficiency.

3.11 General Patient Flow Model

An outpatient clinic is best described as a delivery system that provides health care services for non-residents of that system. Such clinics generally provide a variety of health care services, the number of which is dependent on the size and on the goals of that specific clinic. Clinics specializing in a particular specialty such as orthopedics, family medicine, ophthalmology, and dental would provide highly specialized services related to that specialty. On the other hand, clinics providing general primary health care would offer a broader range of more generalized services such as diagnostic departments including laboratory and x-ray departments, general practitioners, and often a pharmacy.

In an outpatient clinic setting, health care services are generally provided through a group of system components which may or may not be independent, and which may or may not interact with one another. As stated earlier, different services or group of similar services are generally provided at each of the different outpatient clinics. There is more than one type of medical staff personnel assigned to a clinic. In this study, an individual clinic is characterized by the services provided (processes), type of staff assigned to it, and clinic capacity. The patient is considered as an operational link between the independent outpatient clinics. The order in which patients visit outpatient clinics depends on the policies of such clinics, but the inclusion of visits is definitely dependent on the patient's health status, and on the medical practices of the clinic. Although, flow path can exist between outpatient clinics when patients are directed from one clinic to the other, there can be no definite set of flow paths among outpatient clinics. This is because outpatient clinics are found in a wide variety of settings and because they have been established to meet a wide variety of basic objectives. Therefore, the patient's flow paths in a particular clinic are dependent on the mix of regimens prescribed for the patients, clinic setting, and on the general medical procedures recommended as part of the treatment.

3.11.1 Description of the General Outpatient Clinics Model

Typical patient flow in outpatient clinics, emergency, and diagnostic departments in a hospital may be illustrated as shown in Figure 3.3. People with perceived needs for medical care come from a local or regional population to the hospital. The selected population is designated as the 'calling population' for the purpose of this thesis. The facility consists of a set of outpatient clinics, emergency, and diagnostic departments as shown in the figure; a patient receives the necessary treatment at these clinics. The movement of patients from one clinic to another is called a flow path and is designated by arrows in the figure.

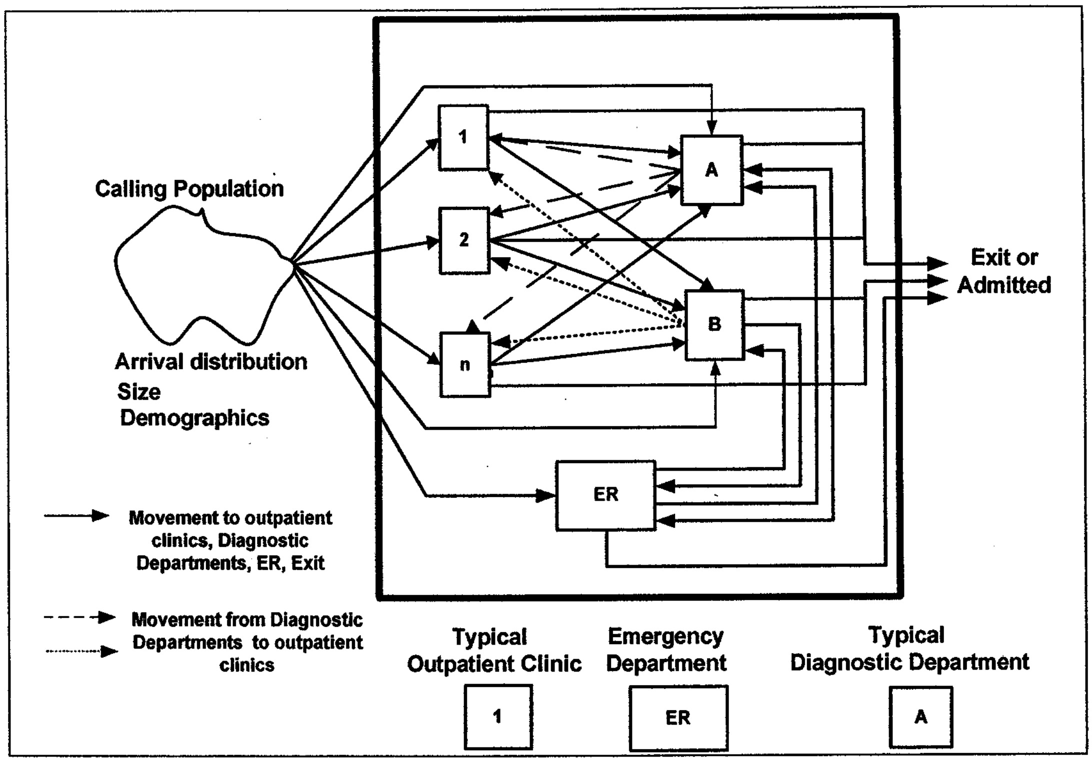


Figure 3.3: General patient flow model

3.11.2 Calling Population

A calling population may consist of any group of people entitled by the health care organization's rules and regulations to receive health care services. This may include military personnel and their families in the case of military hospitals, or the resident of a limited geographical region. Patients coming from the calling population are designated on arrival to the system. Demographics of the calling population and the characteristics of the operating procedures at the clinics influence the arrival and inter-arrival rates of patients. The occurrence of the arrival represents the demand for services on the clinic. Efficient planning and allocating of resources to the value added activities depends on the accurate prediction of the demand for services.

3.11.3 Outpatient Clinics

A clinic is a mechanism through which health care services are provided. The physical configuration of the clinics depends on the operating procedures and the specialty of the clinic. It could include a group highly professional medical staff, assessment and treatment rooms, registration desk, nursing stations, radiology, laboratory, and etc. In this study a clinic is assumed to include medical staff, medical equipment, and other medical supplies required for providing health care services. Individual clinics may not be located in the same physical location. Each clinic includes many servers. Servers can be medical staff that are assigned to the clinic or medical equipment. Medical personnel assigned to the clinics are called "primary servers". Those are personnel who actually provide health care services for patients. For simplicity, only outpatient clinics, emergency, and diagnostic departments are shown in the general model. Servers will be explored in detail for each clinic separately in the next chapter for the purpose of simulation modeling since they have control over the waiting time and services time experienced by individual patients.

Each clinic and department can be characterized by: (1) the number of primary servers available at the clinic or a department; (2) the type of processes or medical services provided; and (3) the queue structure and discipline at the clinic or department. Other unique attributes that might also characterize a clinic or a department include: the mean arrival and inter-arrival rate at the clinic, the number of patient's visits at a point in time; and the mean serving time of server.

As illustrated in Figure 3.3 a patient proceeds to a specific clinic based upon the necessary and required treatment for his/her illness. Arriving patients enter the clinic at the allowable and designated entrance location. These include appointments, walk-in or referral patients. In the clinic a patient proceeds from one server to another based on the regimen of prescribed services. Patient flow in the clinic and the number of servers visited is dependent on the diagnosed illness of the patient and on the established medical procedures for treating this illness. For example, if the patient needs more tests and/or procedure for final diagnosis and treatment, the patient is directed to the diagnostic departments (laboratory and x-ray). Upon the completion of the required tests or procedures the patient returns to the clinic to complete the treatment regimen prescribed and then the patient exits the clinic.

3.11.4 Diagnostic Departments

Diagnostic departments are those like x-ray and laboratory. These departments are often centralized, general-purpose departments, used by multiple primary servers, inpatients wards, and the emergency department. When a department is almost exclusively used by only one specialty, the department is often integrated into the clinic of that specialty. These departments often have the capability of handling walk-in patient flow referred by specialists, or emergency departments for immediate examination. The specimen collection unit determines laboratory capacity, where blood and other specimens are collected. Requests for x-ray procedures and laboratory tests usually are handled as they arrive, with some procedures and tests requiring preparations and an appointment to be made in advance. The types of procedures and tests are decided by the referring department or specialist and based on the patient treatment regimen.

3.11.5 Emergency Department

The emergency department is open 24 hours for providing health care services. Besides its internal capacity, the emergency department often shares resources such as X-rays, clinical laboratory, and pharmacy with other hospital departments. Patients that arrive at the emergency department are of two types: Walk-in patients or EMS patients that arrive by ambulance due to their serious illness. Similar to outpatient clinic patients, emergency patients proceed from one server to another based on the treatment regimen related to their illness. When more tests are needed for final diagnosis and treatment, the patients go to the diagnostic department, and return to the emergency department after completing the required X-ray procedures or laboratory tests. A decision then can be made whether to send the patient home or admit him/ her to the hospital.

3.11.6 Flow Paths

The patient flow path basically represents patient movement throughout outpatient clinics, emergency, and diagnostic departments where he/she receives various medical treatments. The path itself is a logical representation of the interactions and patterns of movements between a patient and the servers. In cases where patients are not able or are not allowed to move from server to server, the flow path would represent the movements of resources (i.e. doctor, nurse, technicians, etc.) to the patient. Movements along a path may be defined in terms of speed and distance, or simply by time. Establishing the flow path for patients and servers movements in clinics and departments are discussed in detail in chapter 4.

3.12 Logic of the Simulation Model

The simulation logic is basically an operational method of representing real life systems (clinics/departments in our case). Each of the following subsections describes the logic of key components of the model.

3.12.1 Entities

In the simulation logic a patient is a dynamic entity. That is, patient after entering the clinics moves from server to server and leaves the clinic after having received the prescribed treatments or medical services related to his/her illness. Typical data that should be maintained during patient movement include: the total number of patient visits to the clinic in a day; the arrival time of the patient at the clinic; the locations the patient visits when proceeding through the clinic; the time of patient arrival and departure at each server in the clinic; patient flow path; the service time at each server; and output performance measure data such as: (a) waiting time encountered by the patient at each server, (b) total waiting time through the clinic; and (c) average length of stay in the clinic. This detailed information is useful only as the patient is proceeding through the clinic.

3.12.2 Locations

Locations represent places in the system where patients (entities) are routed for processing (treatments), decision-making, or some other activities. Locations are used to model a network of servers in each clinic or department. The information set representing locations at a clinic or a department may include: the number of primary servers at the location; the capacity of the location refers to the number of patients (entities) the location can hold or process at any one time; the number of units of a location (multi - capacity locations are used to model locations with common characteristics such as queues, waiting areas, or any other type of location where multiple entities may be held or processed concurrently); location downtime including any setup time where a location can process different types of entities, but needs to be set up to do so; queue structures and disciplines; and level of statistical detail to be gathered for the location and for the clinic. These statistics might include the mean number of patients found at the location or in queues in front of it, the mean waiting time at the location, and location utilization rate. This set also includes service time distribution that is to be experienced by the patient using the location.

3.12.3 Servers (resources)

Servers represent the medical staff and personnel assigned to the clinic or department. A server is represented in the model by resource graphic symbols. If the number of servers (resources) to be assigned to a particular clinic is scheduled to change at certain intervals during the simulation run, they are assigned to shifts. Assigning servers (resources) to shifts means that they can only be used during specifically scheduled hours. The information retained concerning each server may include: server name; server utilization rate; service time distribution at each server; server downtime if any; logic to place it was defined graphically. All this information is stored in the computer memory during the execution of the simulation runs.

3.12.4 Path Networks

As indicated earlier, the movement of patients in a clinic or a department is characterized by the treatment regimens related to their illness. Patients moving by themselves between locations move on path networks using the move logic. When resources are modeled as dynamic resources, which travel between the locations, they also follow a path network. Multiple entities and resources may share a common path network. Movement along the path network may be defined in terms of speed, and distance, or simply by time. In addition, percentages can be used to quantify the flow of patients (entities) in a clinic or a department. Each clinic or department would have a set of such percentages for patients flowing from one server to the other server either from historical records or from direct observation. A properly constructed set of such percentages would undoubtedly provide a good representation of the flows in the clinic or department. There are two types of path networks in the selected software: passing and non-passing. A passing network is used for open path movement where entities and resources are free to overtake one another. Non-passing networks consists of single file tracks or guide paths. Passing and non-passing path networks consist of nodes, which are connected by path segments. Beginning and ending nodes define path segments. Multiple path segments, which may be straight or joint, may be connected at path nodes. The path network editor defines path networks, which is accessed from the build table menu in the selected software.

3.12.5 Arrivals

The arrivals at outpatient clinics, emergency, and diagnostic departments are of two types. These are external arrival from other clinics or departments or internal arrival from server to server within the clinics. Both arrivals represent demand for health care services at each of these clinics and departments. Arrival distributions of patients can be established either from the clinic and department statistics, records, interviews, or observations. Additionally, patient inter-arrival time can be determined using the arrival time distribution. When real times are distributed according to some known mathematical distributions like the Normal or Poisson distributions, then these times may be modeled using fitted distributions. In the selected simulation software, any time new patients (entities) are introduced in the system, it is called an arrival. An arrival record is defined by specifying the following information: (1) number of new entities per arrival; (2) frequency occurrence of the arrivals; (3) location of the arrival; (4) time of the arrival; and (5) total occurrence of the arrival. The frequency of arrival can be defined as either a distribution or as an arrival cycle, which cyclically repeats over time. An arrival cycle is a pattern of arrivals occurring over a certain time period. For example, at the beginning of the day, arrivals to the emergency department may be sparse; but as the day progresses, they build up to one or more peak periods and then taper off. While the total number arriving during the given cycle may vary, the pattern of distribution of arrivals for each cycle is assumed to be the same. Arrival logic is used for performing certain logic as an entity enters the system. An independent arrival is any arrival assigned to occur at a specific time or at a fixed interval. Independent arrival includes processes such as appointments. When defining an independent arrival, the following can be used as guidelines: (1) they may be defined by elapsed time, day and time, or calendar data; (2) assign them to occur at fixed intervals; (3) allow a positive or negative offset to adjust the scheduled time of arrival; (4) define a distribution to allow variability from the adjusted arrival time; (5) allow the possibility that an entity will not arrive at all; and (6) define specific appointment types for only certain resources or resource types.

3.12.6 Time

During any simulation run and after all possible actions have been taken, the simulation clock is advanced to the next earliest event time. There are two types of clock advances in simulation: (1) time-oriented advance; and (2) event-oriented advance. In the time-oriented clock advance the clock time is update at each interval of time after carrying out all possible actions. On the other hand, the occurrence of an event in the system (system state change) triggers clock advance in the event-oriented clock advance. As it is the case in the selected software, simulation languages provide automatic clock control, thus allowing more concentration on model development and output analysis.

3.12.7 Events (processes)

A discrete-event simulation is one in which the state variable of the system changes at a discrete time. An instantaneous occurrence of an event marks this change in the system state. The occurrence of event is triggered by an entity entering (arrival) or leaving (departure) the system. Secondary events occur as a sequence of entity entering or leaving the system. A typical example of a secondary event would be a start of services in a clinic or department. A server can provide service only if it is free or if it has completed working with the previous patient who was first waiting in queue. In the software used, events are called processes. Processes define the routing of entities through the system and the operations that take place at each location they enter. Once entities have entered the system (clinics), processes specify everything that happens to them until they exit the system.

3.13 Overview of the Software Used

Med Model is a powerful windows based simulation tool designed specifically for investigating and analyzing health care systems. It has been used effectively in evaluating, planning, redesigning, and testing new system issues that are related to system inefficiencies without committing the time and resources necessary to build or alter the actual system [88] to [91], [144] to [146]. Med Model focuses on important elements of the health care delivery system; such as resources utilization, system capacity and capability. It is based on object oriented programming using C++ and run entirely under Microsoft Windows, which means that the model's size is limited by the memory available. Moreover, the software contains elements and tools that are useful in addressing unique health care problems that are not found in other simulation software such as Arena, OPNET, Extend, and GPSS/H. For example, the software comes equipped with the ability to read and employ information contained in entity location arrays prepared in spreadsheet format. Simply put, the following characteristics and features make the software standout:

1. Matching entities

The ability to match patients with their supporting medical documents is a necessary capability in delivering health care services. An example is the case where lab tests and x-ray procedures are required for final diagnosis and treatment and movement of results depends on patient movement. Med Model easily handles the requirement to keep identical entities together by using the built-in matching construct provided in the software.

2. Preempting locations and resources

In some situations, such as Emergency situations, where patients require immediate care, it is essential to preempt locations and resources that are occupied by less acute patients. This also may require taking off resources from what they are currently doing and direct them toward theses emergency cases. When that is the case, it is also essential that staff remembers where he or she was in the treatment of the first patient and pick up from that point upon return. To handle this situation, Med Model incorporates an entire hierarchy of preemption constructs that have the ability to preempt locations and take resources from another patient when the new patient condition requires immediate care. It allows setting up an entire level of preemption so that a patient with acuity 1 will be preempted by a patient of acuity 2, an acuity 3 will preempt the acuity 2 level and so on.

3. Subroutine and Macro usage

Health delivery systems are best characterized by many locations capable of having the same activity performed in each location. Few examples include non-specialized operating rooms, clinic exam rooms, and inpatient rooms. Modeling the complex processes and similar activities at different locations effectively is essential when modeling health care delivery systems. Med Model allows the analyst to copy a set of logic statements from one room to another, yet an even better feature is the ability to write the logic once as a subroutine or macro whenever the analyst wishes its logic to be used.

4. Shifts

The shift editor in Med Model is used to manage and schedule resources and their accurate arrival and departure times. Weekly shifts and breaks for locations and resources are defined in the shift editor and may start and end at any minute of the day as shown in Figure 3.4.Single or multiple resources and locations may be assigned to any number of shifts of any length or days of the week.

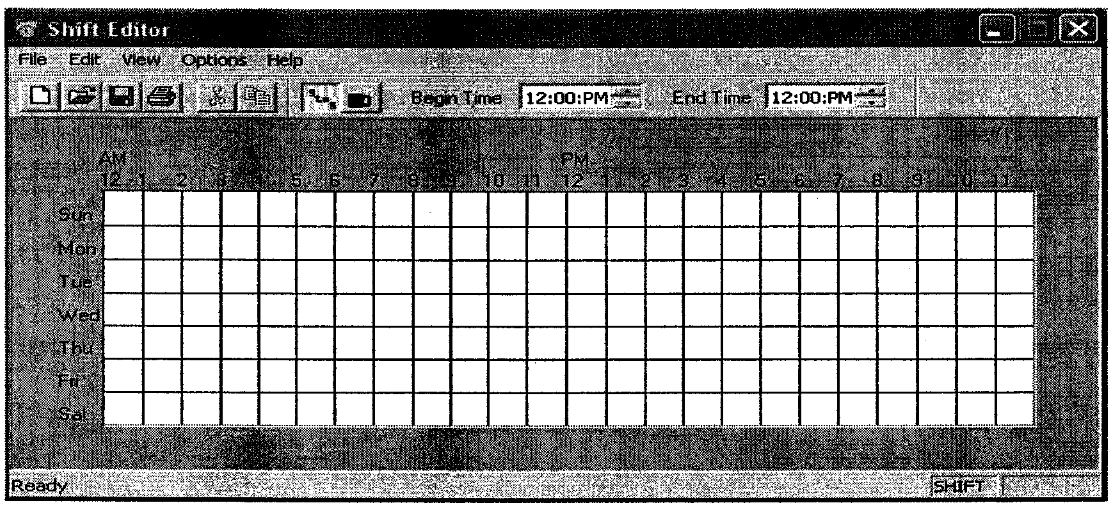


Figure 3.4: Shift Editor.

5. Point and click approach custom Icon

The advantage of Med Model being written under windows allows defining the model by only a click on an appropriate field to select an element for entry of information. The logic builder incorporated in Med Model provides a comprehensive and powerful tool for creating valid logic and expressions.

6. Automatic processing and path entries

Med Model is an adequate tool that presents the modeler with a capability of designing and constructing the model by a mouse click. This is especially helpful when defining the movement and complex processes in the health care delivery system. In that case, the modeler needs only click on the next locations to which the patient may move and the required movement entries are made automatically. This holds true for resources as well. In addition, Med Model automatically enters all distances required to complete movements and calculate correct movement times based on the distance and speed of the moving entity or resources.

7. Custom icons

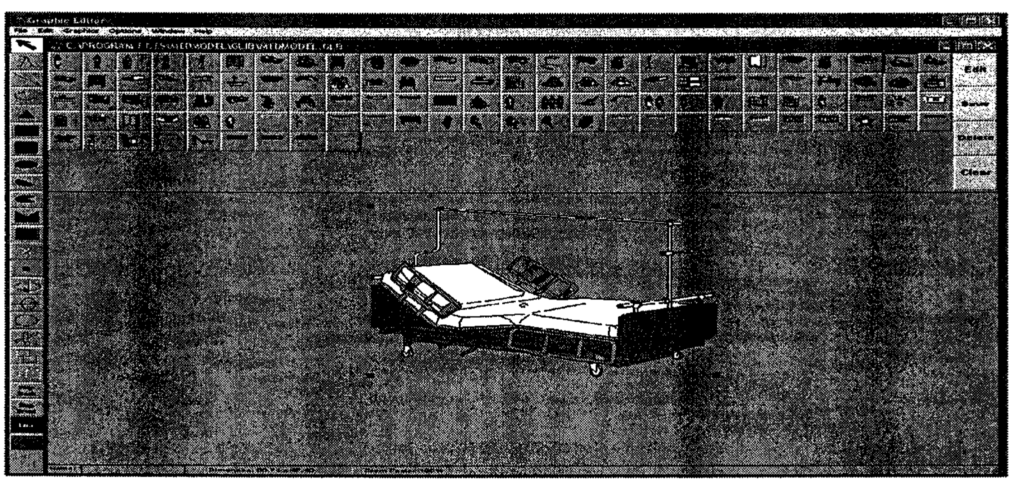


Figure 3.5: Graphic Editor.

Med Model comes with an impressive library of colorful, pre-designed health care icons representing hospital specific patients, staff members, materials, treatment fixture, instruments, used surgical trays, and etc. Med Model also includes an icon editor that enables the design of any manner of icon desired using an almost limitless array of colors and shapes as shown in Figure 3.5. Additionally, it allows drawing new icons using the graphic editor.

8. Dynamic plots

The Med Model dynamic plot feature shown in Figure 3.6 enables graphical observation of statistical information during running time, as well the ability to export this information to an Excel spread sheet. Additionally, it allows import and export capabilities for handling massive data. Results data can be automatically saved as a database tables and read into database applications such as Microsoft access. The statistical data can also be saved as an Excel file. The incorporated output viewer features fully customizable 3D graphs and charts, which allows data documentations and presentation.

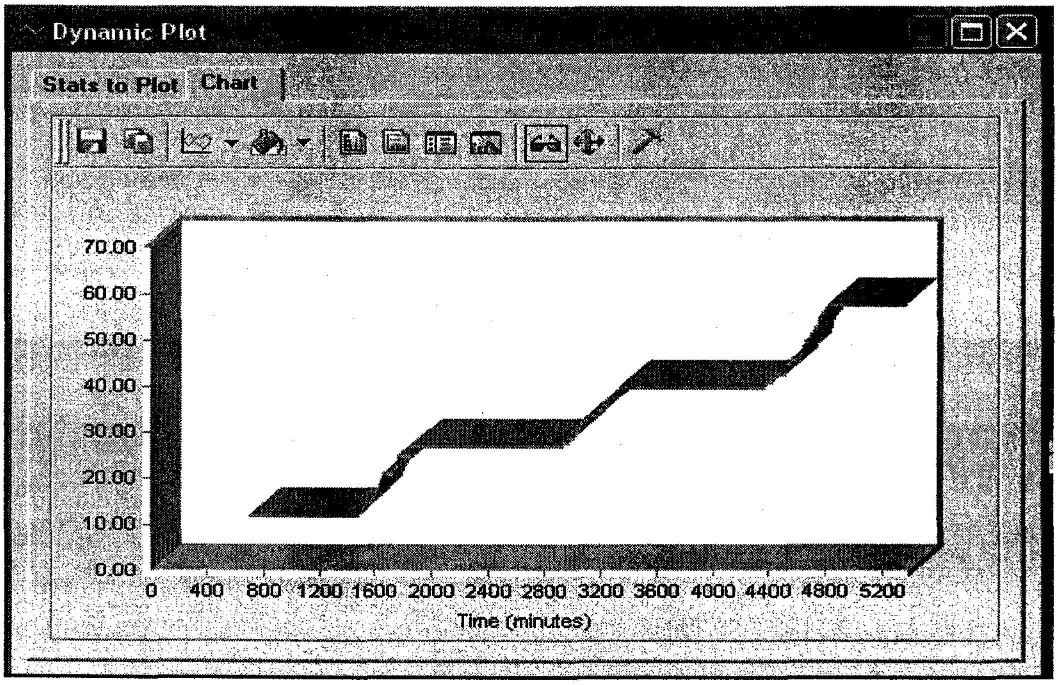


Figure 3.6: Dynamic Plots.

9. Optimization

An added capability to Med Model is the Sim Runner optimization tool. It evaluates the simulation models by performing various what if scenarios, which helps in determining the most ideal way to conduct operations. For each optimization attempt, the analyst feeds information, input factors to change, and how to measure system performance into the Sim Runner. In general, the application of Med Model can be summarized as follows [147]:

- department specific productivity improvement
- facilities design (labs, clinics, radiology, ER's, OR's, etc.)
- planning for future changes
- staff planning
- analyzing patient capacity
- equipment planning and logistical analysis
- emergency preparedness
- bed capacity management

3.14 Justification for Using Simulation and Med Model software

As stated previously, simulation was selected as the main tool for analysis of a health care delivery system at outpatient clinics, emergency, and diagnostic departments because of the structure of such delivery systems is very complex. The specific reasons for using simulation are:

- When modeling a complex health care delivery system, simulation is the only technique that has been successfully utilized when large numbers of random variables must be considered simultaneously.

- Simulation aids the processes of selecting optimal solutions to system inefficiencies for which optimal solutions are unattainable by any known methods of problem solving such as mathematical approaches.
- Simulation is an adequate tool for estimating system variables at any point in time as well as for expanded periods of time; and
- When properly used, simulation can facilitate communication and collaboration.

Med Model simulation software is successfully used by some of the world's leading healthcare organizations including American Red Cross, Baylor Health System, Deaconess–Evansville, HCA, Intermountain Health Care, The Mayo Clinic, MD Anderson, and Miami Valley Hospital. Many other successful applications of the software were reported [147]. The main reason for considering Med Model when modeling health care delivery systems is that it represents an opportunity for incorporating all health care delivery system aspects and environments. It makes replicating the complex health care processes and different interactions easy and efficient. Features and tools incorporated in Med Model that can handle the unique issues in health care delivery systems are rarely contained in other software.

3.15 Summary

It is widely agreeable, that there is higher complexity and uncertainty in managing health care resources. Furthermore, there is also considerable agreement on the factors that contribute to the initiatives that need to be undertaken if an effective and efficient resource management mechanism is to be implemented. The proposed improvement approach in this chapter draws attention to the involvement of stakeholders in the stage of problem formulation/structuring. Moreover, this involvement of problem owners in the modeling process is an attempt to overcome any implementation obstacles and buy in challenges if the new resource management policies were to be implemented. As mentioned earlier in the literature review, the majority of the modeling studies reviewed have overlooked this stage.

In the proposed improvement framework, the modeling process is a closed loop iterative process that is governed by problems owners rather than by predetermined objectives and requirements. Moreover, the iterative process for refining and improving information incorporated in the proposed modeling approach as (PDSA cycle) is valuable for achieving the objectives of the problem owners. It also helps to account for their concerns as it facilitates and enhances their understanding. This understanding about the system is improving through their effective contribution and feedback to the model. Another share of importance in the proposed framework is directed toward the need for gaining an understanding of how the service delivery system works and identifying non-value added activities incorporated in the current delivery system. A detailed description of service delivery processes, activities, and available resources for use is an essential factor towards solving the problem and identifying areas for improvement. Another defining aspect of the proposed improvement framework, that it directs attention toward the post evaluation of optimal solution(s) and the need for effective measures for monitoring and control after the implementation process. Ensuring the effectiveness and efficiency of the model in solving the real problems can be achieved only by enabling problem owners to communicate their feedback, or what they have learned, to analysts and to the model after implementing optimal solution(s). Moreover, this post evaluation process contributes more to the value and usefulness of the model in addressing the real problem owners concerns.

To summarize, the main characteristics that define the novelty of the proposed improvement framework can be summarized as follows:

1) Accounts for problems owner's involvement and input in the modeling process by enhancing the understanding and collaboration among them.
2) The modeling process is a closed loop iterative process that is adaptive to changes rather than a step based process based on predetermined objectives and requirements;
3) Allows identifying underlying reasons contributing to problems such as non valued-added activities that consume resources and time and are of no benefit to the organization;
4) Provides a measure for evaluating the effectiveness and efficiency of implementing new resource management policies through post evaluation.
5) Incorporates a continuous data improvement process for ensuring data reliability, relevancy, and accuracy.
6) Can be used as an adequate control and monitoring tool in developing appropriate solutions to well-defined problems; and
7) Minimizes the modeling variables by focusing only on variables that best describe problem owners concerns.

Chapter 4

Research Methodology and Experimental Setting

4.1 Introduction

This chapter is devoted to describing the experimental setting and methodology used for conducting this research study. The first section of the chapter describes the research setting for the research. Methods for collecting the data required for conducting experiments and data sources are described in section 4.2. Section 4.3 of this chapter gives insight into the steps that have been taken to conduct the external assessment process. Also discussed are the results of the external assessment process. The internal assessment process description and results are presented in section 4.4. Section 4.5 of this chapter addresses an important defining aspect of the proposed improvement framework, process analysis. Also described are the steps for conducting this process, tools used, and data. The last part of this chapter considers the phases of building and developing the simulation model. These phases are: estimating model inputs, development of the simulation model for the case study, model verification, model validation, experimentation, and analyzing output and recommendations.

4.2 Research Setting

Zayed hospital is centrally located in Abu Dhabi in the United Arab Emirates. The hospital was built in the late 1970s and is one of five hospitals within a five-kilometer radius. The hospital services both inpatients and outpatients. The inpatient facility has a capacity of 330 beds, with an average census of 110 patients. Two of the outpatient clinics, namely orthopedics, and the family medicine clinic, two diagnostic departments (Radiology and Laboratory) and the emergency department at the hospital will be used as a research setting for this thesis. Among the reasons for selecting the clinics and diagnostic departments are the following:

(1) The selected clinics are seen as most problematic by hospital management, staff, and end-users of services (patients).

(2) Hospital management was seeking means to increase efficiency and improve processes in outpatient clinics, emergency, and diagnostic departments in an attempt to achieve world-class performance and quality of services.

(3) Problems in the clinics were easily identifiable.

(4) Hospital management and clinical staff agreed to cooperate fully in all phases of this study assuring access to information and data required to estimate appropriate parameters in this study.

(5) The clinics population was homogenous which greatly simplified the estimation and prediction of sample size and future service demand.

(6) The rapidly increasing demand and number of patients in these clinics compared to other clinics as shown in Table 4.1.

Table 4.1: Average number of patients per day at outpatient clinics for the year 2003

(Source: Hospital Statistics Report 2003)

CLINIC NAME	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	AVERAGE
Accident Unit	150	145	151	153	152	126	118	121	143	162	169	158	146
Cardiology	26	29	31	24	26	26	30	27	30	28	19	31	27
Dental Clinic	133	143	102	114	120	154	119	147	117	144	81	124	125
Dermatology	47	47	51	48	36	44	32	39	44	39	35	45	42
ENT	54	57	65	66	72	67	64	45	65	79	49	58	62
Family Medicine	65	68	75	78	84	84	68	78	97	91	72	98	80
General Surgery	22	22	25	24	26	27	27	24	25	25	21	26	24
Neurology	9	7	9	8	9	8	8	8	8	7	7	9	8
OB/GYN	31	32	33	42	41	43	40	36	44	45	35	47	39
Ophthalmology	67	74	68	68	75	69	71	66	72	65	67	65	69
Orthopedics	84	80	89	80	83	87	82	70	83	89	83	116	87
Pediatrics	72	68	96	76	70	67	53	51	75	97	92	87	75
Pediatric Surgery	13	10	6	9	11	12	10	16	19	10	5	8	11
Plastic Surgery	14	17	16	17	16	17	7	10	21	16	14	20	15
Psychiatry	26	32	36	24	27	30	53	44	42	33	25	23	33
Recruitment	29	19	33	30	31	28	33	46	38	31	18	25	30
Urology	13	15	20	20	22	21	19	16	16	22	18	25	19
VIP Clinic	9	13	12	12	12	10	11	3	0	10	10	13	10
Pre Anesthesia	9	10	10	9	11	11	10	12	11	13	8	13	11
Private Treatment	2	2	4	5	7	23	3	1	35	41	24	28	15

4.3 Data Sources and Collections Methods

Modeling complex health care delivery systems like that of Zayed hospital is not an easy task. Extensive data is required to measure end-user and workforce satisfaction, perceptions and concerns. Similarly, defining the current delivery system, bottlenecks, and inefficiencies in detail for simulation purposes is challenging. It was found that in order to make the simulation model operational it requires estimating a large number of system parameters, as we will see in the coming sections. For the purpose of this research and as a strategy for conducting the experiment, the sequential steps shown is Figure 4.1 will be used for our case study at Zayed hospital. To facilitate the data collection process, it was decided to integrate the following data collections tools:

(1) Patient satisfaction survey and comments (see appendix A);

(2) Workforce satisfaction survey and comments (see appendix B);

(3) Interviews; and

(4) Process evaluation forms (process analysis) (see appendix C).

The above data collection tools enabled the exploration of the current service delivery system, and assessed the capabilities and mechanics of the planning and allocation of resources to meet demand at each clinic and department. It also allowed the identification of areas where strengths and weaknesses of the delivery system existed, as well as those that had strong satisfaction and value added activities and elements.

Each one of above tools is explored in detail as they are used in the methodology defined in this research thesis in the following sections.

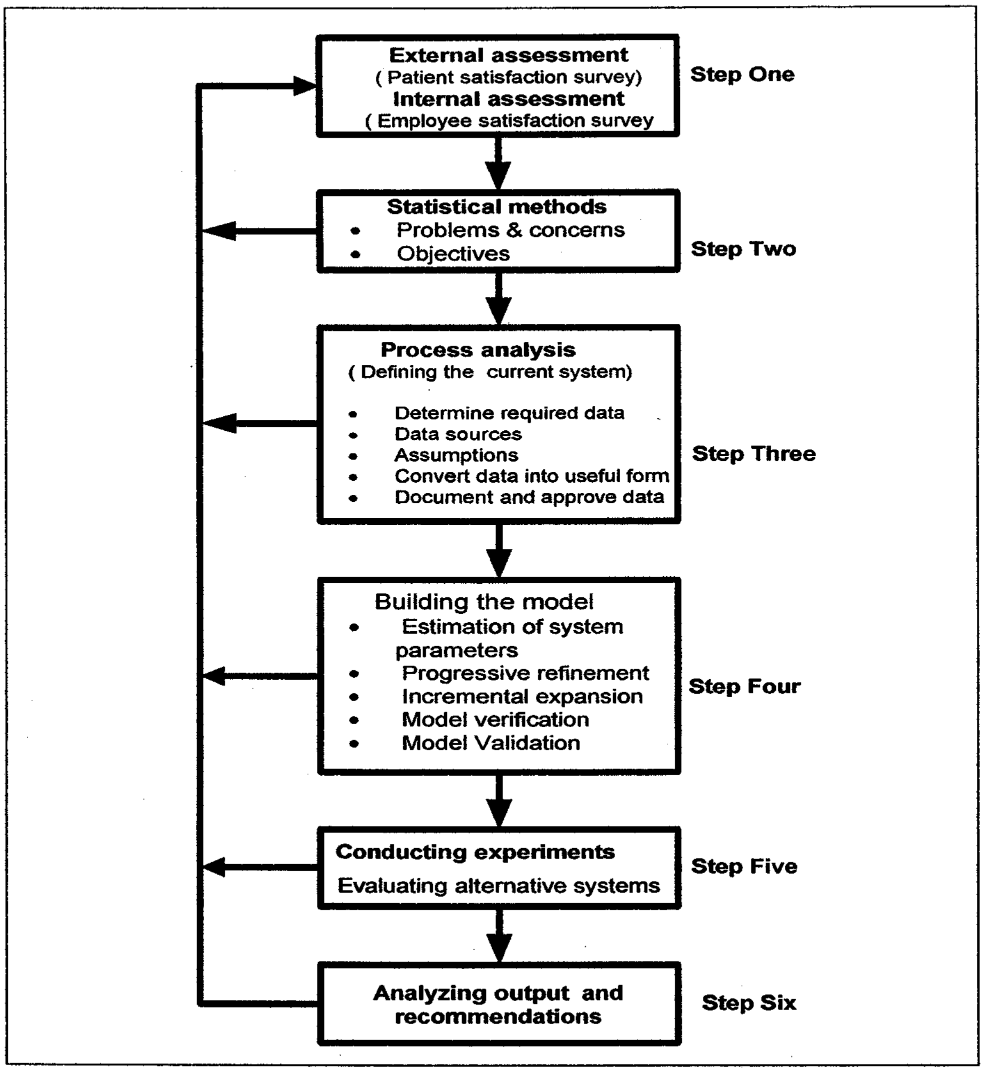


Figure 4.1: Methodology Sequential Steps.

(Note: The Methodology is a closed–loop iterative process)

4.4 External Assessment (Patient Satisfaction Survey)

Surveys are the most commonly used tools for collecting qualitative patient satisfaction data[140]. Measuring how patients feel about how the service delivery system is currently managed can form the foundation for identifying specific action(s) needed to increase delivery system performance, patient satisfaction, and loyalty. In an attempt to ensure reliable, valid, and credible data, considerable attention was devoted to the process of gathering patient satisfaction data at the selected clinics and departments in our study center.

4.4.1 Establishing Survey Objectives

Clearly defining the objectives and scope of the study is critical prior to undertaking the data gathering process. To help arrive at specific objectives, the idea was to try answering two major questions that would be the basis for establishing the survey objectives. The first question was "What is the perception of the current service delivery system, weaknesses, and strengths from the patient point of view?". Answering this question was essential in determining the satisfaction and dissatisfaction determinants in the delivery system. The second question was, "What is the data needed to evaluate and investigate the current system's problems?". For purpose of this thesis, the overall objectives of patient satisfaction survey were:

- To develop and administer means of measuring current patient satisfaction that are health care-centered, and department and provider specific.
- To include the elements of patient satisfaction identified in the simulation modeling process (e.g. waiting time, waiting lists, appointments system, planning for services, allocating resources, and staff utilization).
- To identify 'dissatisfaction areas' for elimination or improvement.
- To identify strong satisfaction determinants. These determinants were used to establish the need and basis for the simulation modeling. In addition, they

provided insight to the current capabilities in managing the delivery of health care processes at Zayed hospital.

4.4.2 Selecting a Survey Mechanism

As indicated earlier, patient satisfaction or dissatisfaction can be determined by a variety of data gathering mechanisms including closed-ended questionnaires[140]. Such questionnaires consist of closely linked satisfaction elements that, when combined, drive each patient's awareness of the perceived service quality and the overall health experience. For the purpose of this study, a closed-ended questionnaire[142] was used to measure patient satisfaction with the health care services in the selected clinics and departments at Zayed hospital. The questionnaire included four general satisfaction elements. These elements are: access, convenience, communication, and perceived quality of health care received. The elements were chosen as quality elements and within each element, specific patient satisfaction/dissatisfaction indicators (quality indicators) were considered as shown in Table 4.2.

Table 4.2: Patient Satisfaction Elements [140]

Access
• Ease of scheduling appointments by phone
• Ease of scheduling appointments in person
• Length of patient waits before seeing health care provider
• Amount of time waiting in reception room
• Amount of time waiting in exam room before seeing health care provider
• Access to medical care in emergencies
• Ease of seeing health care provider of choice
• Ease of getting medical information using a telephone advice system
Convenience
• Location of the hospital
• Working hours of the hospital
• Getting prescriptions refilled
• Getting lab work done when ordered by provider
• Getting X-rays ordered by provider
Communication
• Health care provider's explanation of your medical problem
• Health care provider's explanation of required medical procedures and/or lab tests
• Explanation of prescribed medicine(s)
• Communication between provider and staff
• Willingness of health care provider to listen
• Explanation of any required consents
• Education about ways to manage current health problems
• Education about ways to avoid illness
• Availability of educational programs that teach healthier living
• Reminders to use preventive services
Quality of health care services
• Thoroughness of the health care provider exam
• Amount of time health care provider spends with you
• Thoroughness of medical treatment received
• How well health provider and nursing staff work as a team to serve the patient's health needs
• Overall quality of care from health provider
• Overall quality of care from nursing staff

4.4.3 Determining the Sample Size and Selection Criteria

Two hundred questionnaires were distributed at each of the two selected outpatient clinics, two diagnostic departments, and the emergency department and patients were selected randomly. In determining the required sample size, it was decided that 200 questionnaires would be collected at each clinic. This number was a rule of thumb, but allows for the data to be normally distributed with the sample size for each clinic large enough to ensure that the data is from a normal distribution. The actual number collected was slightly less than 200 for each clinic except the lab, which was lower. Actual number collected (n=912) verses the number planned for 1000 was adequate in showing the quality of the administration of the survey. We can see from Table 4.3 that this ranged from 2% to 15% of the total population, when the total population is taken as the annual average per day over the three week survey period, and between 1.22% and 14.86% of the total population when the average daily population for September is used to estimate the total patient population.

The period of administration of the survey was three weeks in September. This observation period was limited by travel expenses, time to collate the survey, time taken to train survey administrators, and time to raise awareness amongst staff and patients about the survey. There was also some time spent in translating the survey. As stated above the sample size in this three-week period is adequate for the data gathered to be useful.

Table 4.3: Sample size analysis.

Clinic	Average/Sep	Annual Average	Sample Size(n)
Emergency	143	146	194
Family Medicine	97	80	185
Orthopedics	83	86	185
X-ray	127	110	189
Laboratory	620	400	159
			Total = 912

Clinic	Total population (N)*
Emergency	3003
Family Medicine	1455
Orthopedics	1245
X-ray	2667
Laboratory	13020
Total =	21390

* N= Average September X working days
Working days = 15 for family medicine and orthopedics
Working days = 21 for emergency, X-ray and Lab.

Clinic	(n/N x working days)	(n) as % of the total for this period
Emergency	0.06	6
Family Medicine	0.15	15
orthopedics	0.14	14
X-ray	0.08	8
Lab	0.02	2

4.4.4 Determining the Selection Criteria

Patients who best represent the Zayed hospital patient population and having the listed selection criteria were selected. These characteristics include:

- Patients who visited Zayed hospital within the past 6 months
- Patients in the age groups of 20-35, 35-50, and 50+
- Patients of both genders
- Patients with access to transportation, both to and from Zayed hospital.

4.4.5 Administering the survey

Patient satisfaction surveys were distributed on site at each of the two selected outpatient clinics, diagnostic, and emergency departments. In order to facilitate the administration of the surveys, a survey administrator was selected from each clinic and department. The selection criteria for these administrators included individuals who had the following attributes: professional in appearance, friendly, and bilingual (English and Arabic). These individuals were briefed on the survey objectives and how to manage the process of survey administration. During the briefing, all material, including surveys, collection envelopes, and additional supplies, were provided. Then a survey administrator was assigned to each clinic and department. Prior to distributing surveys and in keeping with the research objectives of producing provider-specific data, the survey administrator encoded the predetermined clinic name on each survey. Completed surveys were placed in a completed survey envelope at registration desks located in each clinic and department. Surveys were prepared throughout the day based on demand. At the end of each day, surveys were collected from each area for evaluation. Each questionnaire that appeared to be completed was inspected carefully. Each page and section was checked to see that the respondent followed instructions and recorded responses in the proper places. Surveys where entire sections were left blank or the respondent completed only the beginning portion were rejected. Although some patients did not welcome the idea of completing these surveys, the majority looked at it as the first opportunity to voice their concerns and perceptions and contribute to the overall improvement efforts.

4.4.6 Enter and tabulate the data

A total of (n= 912) "Patient Satisfaction Questionnaires" were collected from participants seeking health care services at Zayed hospital (ZH) in a spectrum of clinic and department settings. The survey consisted of questions A1 through A8, pertaining to health care access issues; B1 through B3, dealing with issues regarding convenience; C1 through C7, communications; D1 through D10 which dealt with quality of care; and E1 and E2 dealing with general satisfaction of healthcare delivery – additionally asking for a qualitative statement of what the participants considered to be the major areas for potential improvement. Questions A1 through E2 assess the participant's overall agreement with the given question (1=strongly agree, 2= agree, 3=uncertain, 4=disagree, 5=strongly disagree). As well, two demographic variables were collected: age, a continuous variable, and gender, a categorical variable. The data was entered manually into an MS Excel spreadsheet, and all fields with missing data were left blank. The variables were coded as follows:-

Clinic Type:

F = Family medicine, X = X-Ray, ER=Emergency Unit
OC = Ortho clinic, L =Laboratory

The completeness of the MS Excel data file was assessed by visually comparing the records against the respective original questionnaire. The accuracy of the data file was examined by determining if all the variables in the data file were in the appropriate range, i.e. 1 through 5 for questions A1 through E2, the correct range for clinic type and gender, and age was checked for the presence of outliers i.e. an age of 2 or 107.Once data entry and clean up were completed, the MS Excel file was saved as a 'Microsoft Excel 97-2002

& 5.0/95 Workbook', compatible for use in SAS v8. The subsequent file was imported into SAS and saved into a permanent SAS directory, allowing the file to be accessed during future SAS sessions. In SAS, steps such as variable assignment and formatting were completed in order to prepare the data file for future analyses. Missing data were recoded allowing them to be included in the analysis, and text variables were converted into numeric variables.

4.4.7 Demographic Overview of Participants

The frequency distribution of patient demographic variables was analyzed for (n=912) individuals who completed the "Patient Satisfaction Questionnaire" at the selected clinics and departments in SAS using the 'PROC FREQ' statement. The variables analyzed included the clinics and departments at ZH in which the patient was seeking medical care; the age of the patient, which was treated as a categorical variable; and gender. A detailed overview of the frequency distribution of the aforementioned variables is included in Table 4.4. Of interest, 21.3% of the respondents seeking medical care at the emergency room, 59.2% were females, and 37.5% of the participants were between the ages of 25 and 34.

Table 4.4: Absolute and relative frequencies of patients.

VARIABLE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (%)
Clinic type		
LABORATORY	159	17.4
FAMILY MEDICINE	185	20.3
EMERGENCY	194	21.3
X-RAY	189	20.7
ORTHO CLINIC	185	20.3
Gender		
FEMALE	540	59.2
MALE	372	40.8
Age group (years)		
Under 25	178	19.5
25-34	342	37.5
35-44	259	28.4
45 plus	118	13.0
Missing data	15	1.60

4.4.8 Data Analysis

The data analysis process involved the transformation of raw data accepted for the purpose of this study into a form making this data easy to understand and interpret. This stage included the rearranging, ordering, and manipulation of the data to provide descriptive information.

4.4.9 Patient Satisfaction Questionnaire (via Clinic Type)

The frequency distribution of patient demographic variables was analyzed for 912 individuals who completed the "Patient Satisfaction Questionnaire" at ZH in SAS using the 'PROC FREQ' statement, differing in that a frequency distribution was performed for each of the five clinic types: laboratory, family medicine clinic, emergency, X-ray department, and Ortho clinic). Demographic variables were analyzed including gender, and age group. Overview of frequency distribution of indicted variables can be found in Table 4.5.

Table 4.5: Absolute frequencies of patient demographics by clinic type for (n = 912) participants.

VARIABLE	LAB	Family	ER	X -Ray	Ortho
Gender					
Female	94	110	115	112	109
Male	65	75	79	77	76
Age group (years)					
Missing data	2	3	4	3	3
Under 25	32	36	38	36	36
25-34	61	69	72	71	69
35-44	44	53	55	54	53
45 plus	20	24	25	25	24

The frequency distributions of questions A1 through E2 were examined using the PROC FREQ procedure in SAS. Due to the occurrence of multiple zero cells in the frequency distribution of questions A1 through E2 as per the previous coding with 5 categories (1=strongly agree, 2= agree, 3=uncertain, 4=disagree, 5=strongly disagree), the questions were recoded to consist of 3 categories (1=missing/uncertain, 2=disagree, and 3=agree). By combing category 3 from the previous coding setup with missing variables, we created the category 'missing/uncertain'; 'disagree' resulted from the combination of categories 4 and 5; and 'agree' resulted from the combination of categories 1 and 2.

In this survey, a large amount of variables had less than 50% agreement or less than 50% disagreement for positive and negative statements, respectively. In order for a variable to be considered important, it was decided that variables with greater than 60 percent disagreement for positive statements (e.g. 'If I have a medical question, I can reach a doctor for help without any problem'), or greater than 60% agreement for negative statements (e.g. 'The office where I get medical care should be open more hours') in one or more clinic categories were to be retained for future characterization and reporting. This is in addition to those variables with less than 50% agreement or disagreement. Tables 4.6 [a], [b] contain a detailed overview of variables meeting the greater than 60% level, specifically with a listing of clinics which met the aforementioned criteria.

Table 4.6 [a]: List of clinics by questions, with greater than 60 % agreement (A) or disagreement (D) to positive statements.

NO.	QUESTION	L	FM	ER	X	OC
Access						
A1	It is easy for me to get medical care in an emergency			D		
A7	I am able to get medical care whenever I need it		D			
A8	If I need hospital care, I can get admitted easily					
Convenience						
B1	The office hours when I get medical care are convenient for me	A	A	A	A	A
B3	Places where I get medical care are well located					D
Communication						
C6	If I have a medical question, I can reach a doctor for help without any problem					
Quality of Care						
D3	The medical staff that treat me knows about the latest medical developments	A		A	A	A
D4	Doctors never expose me to unnecessary risk	A	A	A	A	A
D6	Overall, the medical care I receive is excellent	D	D	D	D	D
D1	My doctor is very competent and well trained			A	A	A
General Satisfaction						
E1	I am very satisfied with the medical care I receive	D	D	D	D	D

Table 4.6 [b]: List of clinics by questions, with greater than 60 % agreement (A)or disagreement(D) to negative statements.

NO.	QUESTION	L	FM	ER	X	OC
Access						
A2	I am usually kept waiting for a long period of time	A	A	A	A	A
A3	It is hard for me to get medical care on short notice	A	A	A	A	A
A6	It is hard to get an appointment for care right away	A	A		A	A
Convenience						
B2	The office where I get medical care should be open more hours					A
Communication						
C5	Doctors sometimes ignore what I tell them	A	A	A	A	A
C6	If I have a medical question, I can reach a doctor for help without any problem					
Quality of Care						
D2	Sometimes, doctors make me wonder if their diagnosis is correct					A
General Satisfaction						
E2	There are some things about the medical system that need to be improved	A	A	A	A	A

Additionally, an assessment of the qualitative statements given when asked about the areas for improvement at ZH was completed. This was done in SAS by coding the comments as categorical variables, and completing a frequency distribution of the resultant comments, by clinic type. The categories included: appointment waiting list, clinic waiting time, medical records (misplaced, lack of co-ordination), staff shortage, quality of care, laboratory results, quality of room, quality of waiting room, admissions procedure, and waiting for x-ray. A visual representation of the frequency distribution for the comments can be found in Figures 4.2 to 4.6. Of interest, the greatest area for improvement was clinic waiting time in most of the departments/clinics.

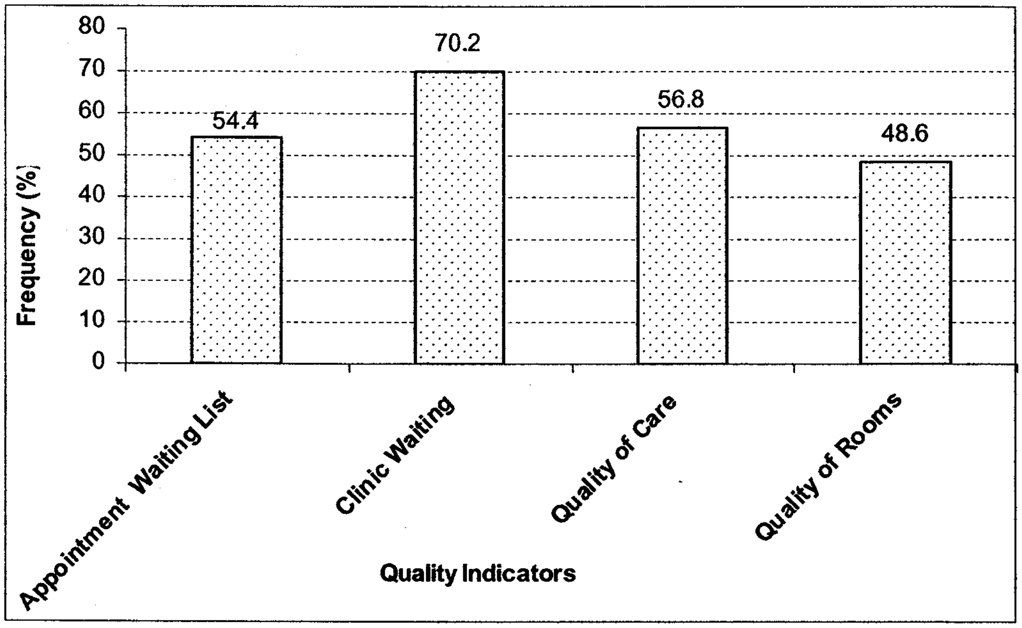


Figure 4.2: Frequency of quality indicators for 'Areas of improvement at ZH'- x-ray Department.

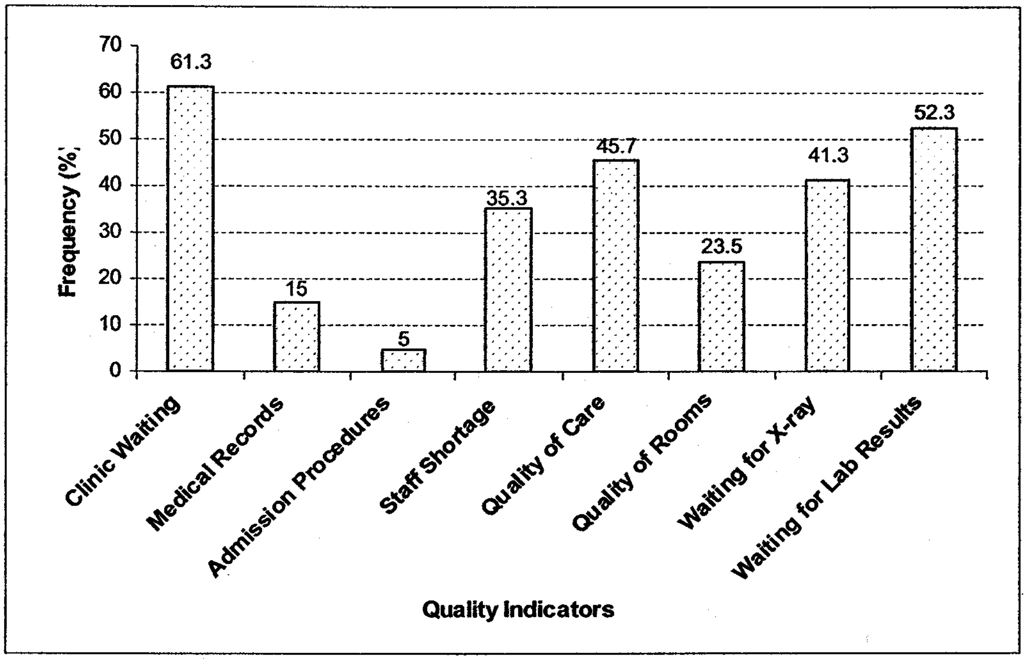


Figure 4.3: Frequency of quality indicators for 'Areas of improvement at ZH'- Emergency.

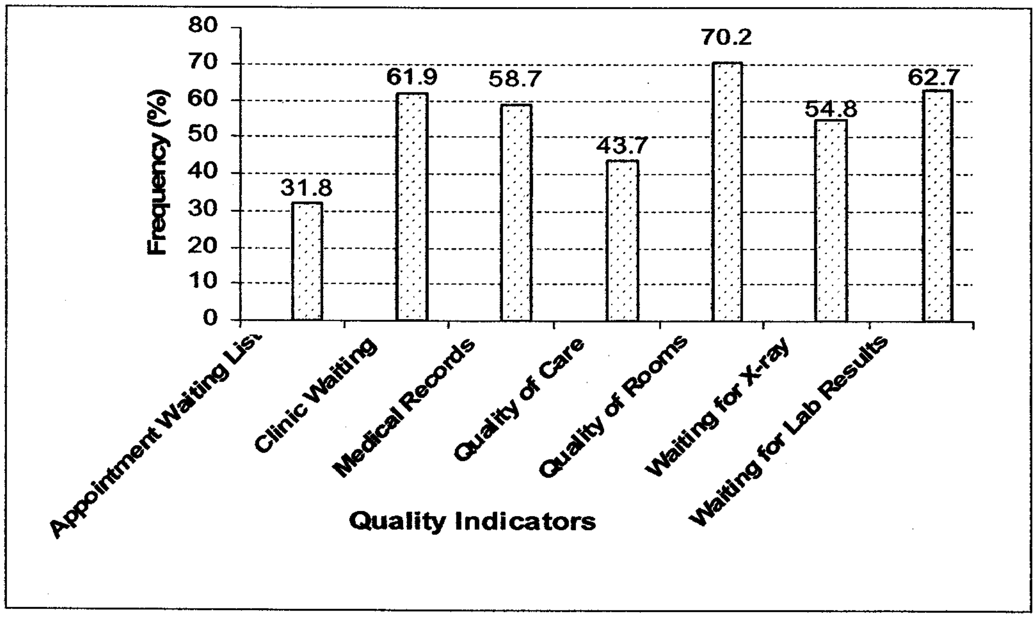


Figure 4.4: Frequency of quality indicator 'Areas of improvement at ZH' - Family medicine.

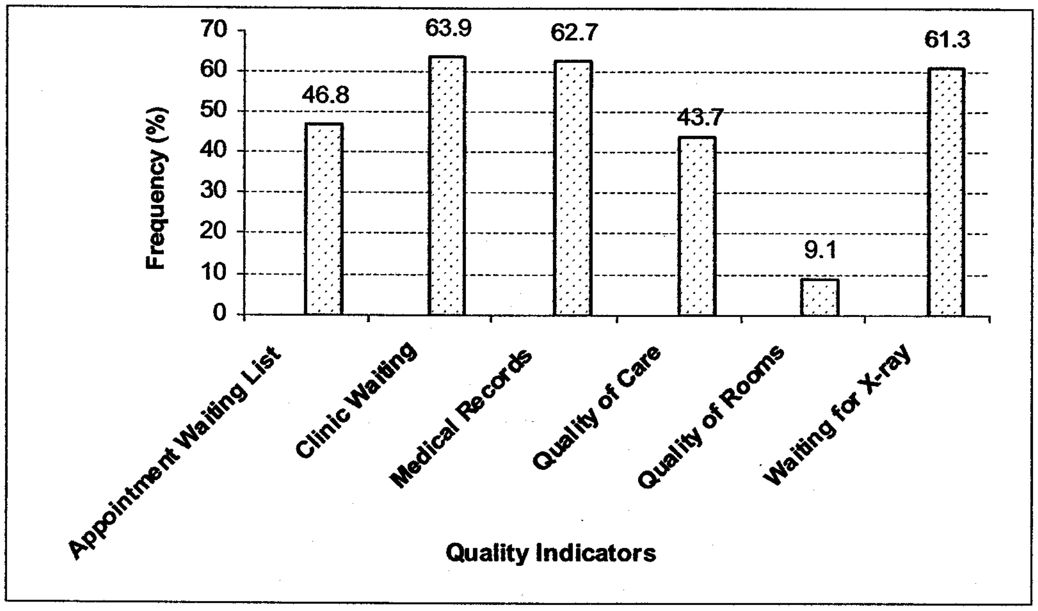


Figure 4.5: Frequency of quality for indicators 'Areas of improvement at ZH'- Ortho clinic.

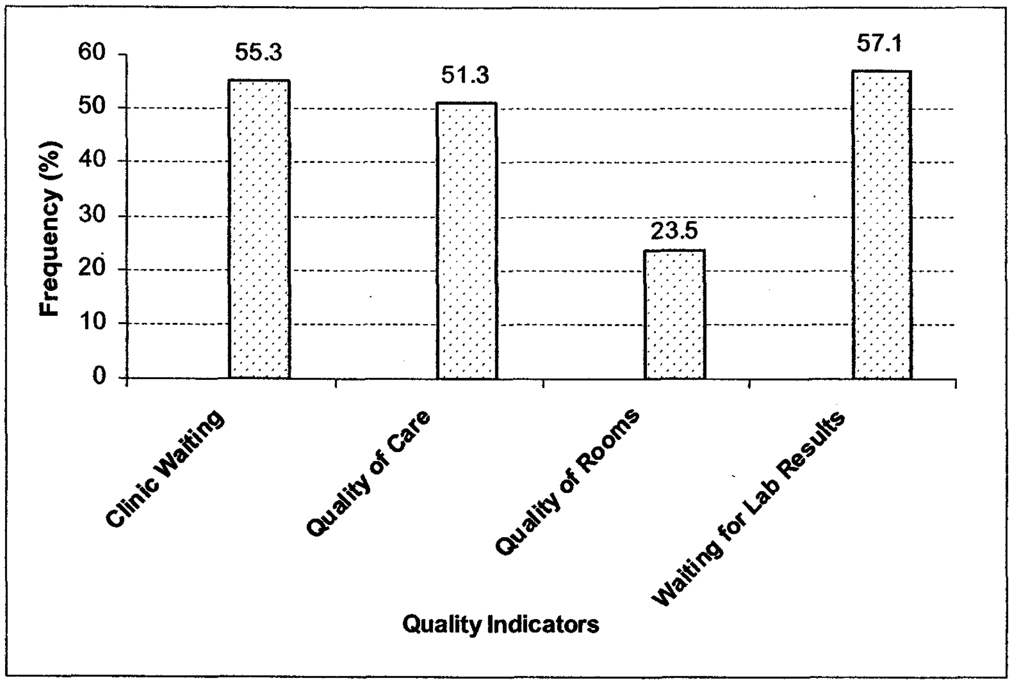


Figure 4.6: Frequency of quality indicators for 'Areas of improvement at ZH'- Laboratory.

4.4.10 Summary of Survey Results

When examining access, convenience, communication, quality of care, and general satisfaction by clinic type, it was found that each clinic had a different profile of variables identified to be in agreement or disagreement by a large majority (>60%) of the respondents. In terms of health care access, all clinics had areas of concern. The primary issues included access to medical care in emergencies or on short notice, and waiting times. When analyzing issues of convenience, patients' responses were of major concern when examining clinics. Communication was identified to be an issue of concern in all. Quality of care at Zayed hospital as perceived by the patient was an issue in all clinics, as was general satisfaction. In the x-ray department, as shown in Figure 4.2, appointment waiting lists, clinic waiting time, quality of care, and quality of rooms were identified as problems and in need of improvement. The major areas of improvement when assessing respondent's comments in the emergency department included: clinic waiting time, medical records, admission procedures, staff shortage, quality of care, quality of rooms, waiting for x-ray, and waiting for laboratory results as shown in Figure 4.3. In the family medicine clinic respondents identified appointment waiting lists, clinic waiting time, medical records, quality of rooms, quality of care, waiting for x-ray, and waiting for lab results as areas which are in need of improvement as shown in Figure 4.4. In the Ortho clinic as shown in Figure 4.5, appointment waiting list, clinic waiting, medical records, waiting for x- ray results, quality of rooms, quality of care were cited as major areas of concern.

As illustrated in Figure 4.6, only four areas were identified to be in need of improvement in the laboratory. These areas include: clinic waiting time, quality of care, quality of rooms and waiting for lab results.

4.5 Internal Assessment (Employee Satisfaction Survey)

Many hospitals conduct employee surveys as part of the institution's ongoing satisfaction measurement practices. At Zayed Hospital, conducting a work satisfaction survey serves to gauge employee opinion on workplace issues and attitudes which are important to the modeling process. The annual Ottawa hospital employee satisfaction questionnaire (see appendix B) was used for this thesis with some modification related to the work environment and the health care setting at Zayed hospital. The questionnaire contains issues believed to be important for the employee satisfaction metric and can test a wide range of variables that are impacting the workplace. The information gathered from the questionnaire is used to identify statistical trends in certain groups and to provide the management with platforms for action in areas identified as challenges. Additionally, such qualitative method provided an insight to the availability of certain resources to accomplish certain tasks and the current planning and allocations practices at each clinic and department understudy.

4.5.1 Sample Size and Selection Criteria

In determining the sample size and target population for staff, it was necessary to seek a reasonably number of participants and to ensure the involvement of different staff level at each department and clinic. Twenty questionnaires were randomly distributed at each clinic and department of concern using the same clinics as in the patient survey. In Table 4.7 a brief calculation of the sample size is given.

Table 4.7: Employee sample size calculation.

Clinic	Total number employed (N)	Sample Size (n)
Emergency	45	20
Family Medicine	52	17
Orthopedics	36	18
X-ray	62	19
Laboratory	70	19
Total	255	93
Clinic	**Ratio sample size to employee total (n/N)**	
Emergency	0.44	
Family Medicine	0.40	
Orthopedics	0.50	
X-ray	0.29	
Laboratory	0.27	

As shown in the table above, the actual number collected was slightly less than 20 for each clinic/department except the emergency. Actual number collected (n=93) verses the number planned for 100 was adequate in representing the total staff population at the selected clinics and departments. The ratio of sample size this ranged from 27% to 50% of the total staff population.

Meetings with clinic and department heads were conducted to justify the need for the survey and to seek the participation and involvement from all staff levels. Additionally, in order to ensure different background feedback, the selection criteria established for the target population included: administrative, clerical, technicians, nursing, and physicians. The appointed survey administrator distributed surveys to all different staff level. In the events where participants asked to take surveys home they were allowed to with a one-week turnaround time. During this period, some staff had some concerns related to the confidentiality of their feedback. Providing the participants with envelopes assured them complete confidentiality of their feedback thereby solving this problem.

4.5.2 Methodology and Data Entry

A total of 93 "Physician and Employee Satisfaction Surveys" were collected from participating health care professionals and support staff (physicians, nurses, technicians, clerks). The survey consisted of 105 questions pertaining to various work-related and demographic issues.

All entries were verified by comparing the MS Excel data file against the original questionnaire. The accuracy of the data file was examined by determining if all the variables in the data file were in the appropriate range, i.e. 1 through 6 for questions 1 through 97 and the correct range for questions 98 through 105. Once data entry and clean up were completed, the MS Excel file was saved as a 'Microsoft Excel

97-2002 & 5.0/95 Workbook', compatible for use in SAS v8. The subsequent file was imported into SAS and saved into a permanent SAS directory, allowing the file to be accessed during future SAS sessions. In SAS, steps such as variable assignment and formatting were completed in order to prepare the data file for subsequent analyses. The recoding of questions 1 through 97 resulted in a total of 7 categories for each variable (1=missing, 2=completely disagree, 3=somewhat disagree, 4=somewhat agree, 5=completely agree, 6=don't know, and 7=not applicable); clinic type consisted of 5 categories (1= x-ray, 2=emergency department, 3= Ortho clinic, 4=laboratory, 5= Family clinic,); occupation consisted of 6 categories (1=missing, 2=physician, 3=nursing, 4=manager/director, 5=administrative, 6=clerical); length of time employed consisted of 7 categories (1=missing, 2= < 5 years, 3=5 to 10 years, 4=11 to 15 years, 5=16 to 20 years, 6=21 to 25 years, 7=over 25 years); gender consisted of 3 categories (1=missing, 2=male, 3=female); and age consisted of 7 categories (1=missing, 2=under 25, 3=25-34, 4=35-44, 5=45-54, 6=55-64, 7=65 plus).

4.5.3 Demographic Overview of Participants

The frequency distribution of physician and employee demographic variables were analyzed for the 93 individuals who completed the "Physician and Employee Satisfaction Survey" at ZH in SAS using the 'PROC FREQ' statement. Variables of interest included clinic type, occupation, length of time employed at the ZH, gender, and age group. A detailed overview of the frequency distribution of the indicated variables can be found in Table 4.8. Of interest, 22%of the population worked in the emergency room, 53% were nurses by profession, 59% had worked at

ZH for less than 5 years, 55% were females, and 38% were in the age range of 25 to 34.

Table 4.8: Absolute and relative frequencies of employee demographic for (n=93) participant.

VARIABLE	ABSOLUTE FREQUENCY	RELATIVE FREQUENCY (%)
Clinic type		
Family medicine	17	18.3
Emergency room	20	21.5
Ortho clinic	18	19.4
Laboratory	19	20.4
X-ray	19	20.4
Missing data	0	0.00
Profession		
Physicians	21	22.6
Nursing	49	52.8
Manager, Director	8	9.40
Administrative	7	7.60
Clerical	4	3.80
Missing data	4	3.80
Length of time (years)		
Less than 5	54	58.5
5 to 10	22	24.5
11 to 15	4	3.80
16 to 20	7	7.50
21 to 25	2	1.90
Over 25	0	0.00
Missing data	4	3.80
Gender		
Female	51	54.7
Male	37	39.6
Missing data	5	5.70
Age group (years)		
Under 25	14	15.1
25-34	35	37.7
35-44	24	26.4
45-54	11	11.3
55-64	4	3.80
65 plus	0	0.00
Missing data	5	5.70

4.5.4 Frequency Distribution of Questions

The frequency distributions of questions 1 through 69 were examined using the PROC FREQ procedure in SAS. Due to the occurrence of multiple zero cells in the frequency distribution of questions 1 through 69 as per the previous coding (7categories), the questions were recoded to consist of 3 categories (1=missing, unsure, not applicable, 2=disagree, and 3=agree). The category 'missing, unsure, not applicable' was created by combining categories 1, 6 and 7 from the previous coding step, 'disagree' resulted from the combination of categories 2 and 3, and 'agree' resulted from the combination of categories 4 and 5 (refer to the previous coding step for clarification).

In general, agreement was greater than 50% for positive statements, and less than 50% for negative statements, with the exception of a few variables highlighted in Table 4.9 deemed to be of particularly important. In order for a variable to be considered of interest, it was decided that variables should have greater than 60% disagreement for positive statements (e.g. 'overall, the work I do, I am satisfied with my pay') amongst the responses. This same criterion was applied to agreement for negative statements (e.g. 'ZH does not provide a supportive environment for employees and physicians'). These were to be retained for future characterization and reporting. Table 4.9 contains a detailed overview of variables having this greater than 60% response level, and their overall agreement/disagreement for the respective variable.

Table 4.9: List of questions with 60% agreement (or disagreement, where indicated) and corresponding percent agreement.

NO.	QUESTION	% Disagreement	% Agreement
6	Within the next 3 to 5 years ZH can become one of the best hospitals in UAE		69.8
9	Satisfaction with your influence over your work schedule		69.8
11	Overall, the work I do, I am satisfied with my pay		62.3
13	I do not have opportunities for advancement or promotion	62.3	
14	I feel insecure about my future employment at ZH	62.3	
16	I would prefer to remain with ZH even if I were offered a comparable job in another hospital		66.0
17	ZH makes a good use of human resources available	66	
18	In my work area, the human resources available are used inefficiently		58.5
19	ZH maintains effective partnership with other health social services providers for the benefits of the community		69.8
22	The equipment/tools I use are poorly maintained	67.9	
24	My work area has few staff to fulfill its responsibilities		60.4
28	I am satisfied with the professional practice support I receive at ZH		62.3
30	In my work area, some of the people do most of the work while others do enough to get by		58.5
41	Good staff performance is recognized at ZH		69.8
44	I have a clear understanding of the overall goals of ZH		66.0
50	Provides the training I need to do my job well (senior management)		69.8
67	Acts on suggestions and/or recommendations from staff (senior management)		69.8

4.6 Process Analysis

Defining the current service delivery system is basically identifying the system that will be simulated in detail. This step can be viewed as the development of the conceptual model for each clinic and department under study. Conceptual models are used as baseline models for simulation. The purpose of this step is to understand the operational aspects of the service delivery system, identify bottlenecks and inefficiencies, and determine the non-value added activities that are of concern to patients, workforce, and management. This phase included the following five steps:

- Determine the required data for defining the current service delivery system[143];
- Determine data sources;
- Make assumption in the case of unavailability of accurate and reliable data;
- Convert data into useful form (data tables, relational diagrams, and frequency distributions); and
- Approve data

Having a specific set of data for defining the current service delivery system ready, the next step was to search for this required data. One principal aim of identifying the current service delivery system is the collection of valid and timely data in a practical and effective manner. To collect the predetermined set of data required for identifying the service delivery systems under study it was important to review hospital statistical reports and records, review facility layout, conduct personnel interviews, use flowcharts, develop a process evaluation form and observe the system for some time. The importance of the involvement and cooperation from key personnel in each clinic and department in the evaluation process was well noted. It was first important to conduct interviews with staff from different levels and seek their support and cooperation. Staff with direct involvement with the daily operational activities at each clinic and department was selected as a source of information and to validate collected data and approve it.

4.6.1 Flowcharts

Flowchart diagrams as shown in Figure 4.7 were created based on inputs from clinic and department staff to document the processes and patient flow during interview times. Each clinic process flow chart was validated by the appropriate clinic staff and is used in building the simulation models.

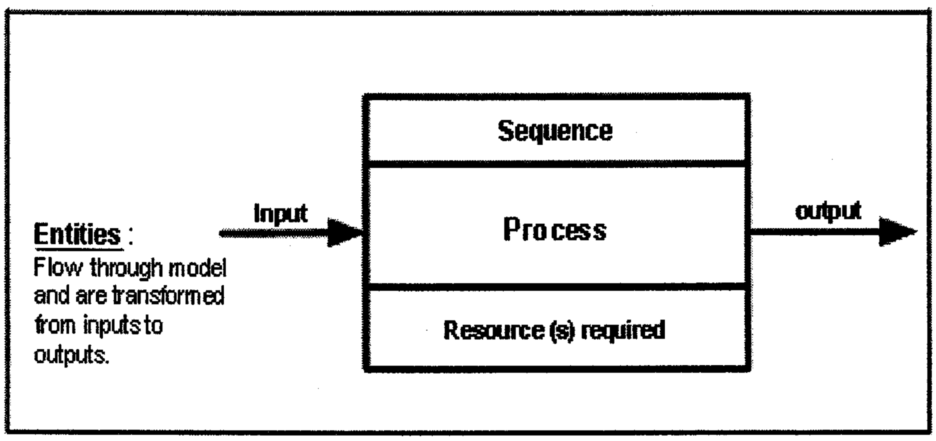


Figure 4.7: Flow chart diagram.

4.6.2 Process Evaluation Forms

Limitations in the previous evaluation tools and data sources existed. One limitation is how each individual interpreted the operational aspect of the delivery system and conducted assigned tasks. The second limitation is that the majority of data collected from patient and employee satisfaction surveys are qualitative data and not sufficient to build a valid simulation model. At that time, it was important not to rely only on estimates and qualitative data for evaluating and modeling the service delivery system. Consequently, it was important to develop a practical tool or evaluation mechanism to investigate and evaluate the operational aspects of the delivery system in real time and collect quantitative data for simulation modeling purposes. The collected data is then used to verify and validate the simulation models. In doing so and based on validated process flowcharts for each clinic and department, process evaluation forms that included the operational aspect of each clinic and department were constructed (see appendix C). These forms were structured based on the validated process flowcharts from each clinic and department and included process type based on their sequence of occurrence, resources required, arrival time, and process time. Before starting the evaluation process, a meeting with all different staff levels at each clinic and department was conducted. The purpose of the meetings was to explore the contents of the evaluation form, objectives, and to facilitate the evaluation process. At the meetings many of staff voiced their concerns as they looked at the evaluation process as an inconvenient task for them and the collection of these data had the potential for interrupting the delivery of health care services. Moreover, some staff looked at this as extra workload for them and raised concerns about the data required in completing the evaluation forms. In an attempt to manage this problem, the evaluation forms were reconstructed taking staff concerns into consideration. The new evaluation forms required recording the arrival time of the patient by a receptionist, start and end time of each process by the care provider as the patient proceeds through the clinic or department. Resources involved in each process, and shift type are recorded prior to the evaluation process based on staff approval. The evaluation forms are then attached to the patient medical record as it proceeded with the patient throughout the department or clinic. In the case of walk-in patients, the receptionist recorded the arrival time and wait time for the arrival of the medical record before attaching the process evaluation form. For urgent cases such as an EMS patient at the emergency, where providing the services starts without waiting for the medical record, the receptionist records the arrival time and passes the evaluation form to a nurse to complete the form. Evaluation forms were kept at the registration desk of each department and clinic under-study and collected at the end of each shift. A receptionist was assigned to manage the distribution and collection of the evaluation forms. Collected data was then analyzed and results were used to estimate and validate the system parameters, as we will see in the next section.

4.7 Building the Simulation Models

One of the main objectives for constructing simulation models for the selected clinics and departments at Zayed hospital is to maximize the likelihood that the simulation results can be utilized. The phases that are used to build the simulation models are: (1) preparation and estimating system parameters, (2) development of simulation models, (3) model verification, (4) model validation, (5) conducting experiments, and (6) analyzing output and recommendations. The point that should be stressed here is that clinic and department staff involvement and participation in building the simulation model is essential to the simulation modeling process. Their knowledge of the operational aspects of the delivery system is important if the simulation models were to be successful. In addition, their involvement in the meaningful aspects of the modeling process increases the likelihood that they will understand the capability of simulation modeling and support its use as an evaluation tool and facilitate the implementation of new changes.

4.7.1 Preparation and Estimating System Parameters

The first step in this phase is to develop valid objectives for the simulation model that best describe end-users (patients) and staff concerns and problems. Well-defined objectives are then used to identify essential decision variables and the important operational aspects that should be modeled. The decision variables considered for this study include: resource utilization rates and patient throughput at the selected clinics and departments. The second step is to define the operational parameters of the simulation models of the delivery system as shown in Table 4.10.

Table 4.10: Simulation parameters.

Parameter	Description	Source
Patient load	Number of patients at each clinic and department(hourly, daily, monthly, annually)	Interviews, collected data, hospital records
Entities	What the model processes (walk-in, with appointment, or urgent patient)	Interviews, collected data
Locations	Places where entities are routed for processing or some other activities.	Interviews, collected data, hospital records
Processes	Defines the routing of the entities through the system, operations that take at each location they enter, and process duration.	Interviews, collected data
Path networks	The path in which dynamic resources and entities travel.	Interviews, clinics layout
Patient flow percentages	Patient flow (movement) percentages associated with each server and also patient flow from and to clinics and departments	Interviews, collected data
Patient length of stay	The total time the patient spend in the system (processing time + waiting time)	Interviews, collected data
Queues	Structure and discipline first in first out (FIFO), last in last out (LIFO)	Interviews, observation
Primary servers (Resources)	The number and type of medical care personnel, locations, and equipment assigned to each process	Interviews, collected data, hospital records
Patient arrival	Number of new entities per arrival, frequency of arrival, location of arrival, time of the first arrival, and total occurrence of the arrival.	Collected data
Shifts	Define the weekly shift and breaks for locations and resources.	Interviews, observation, hospital records

4.7.2 Development of Simulation Models

Developing the simulation models for the selected clinics and departments at Zayed Hospital involves the key elements shown in Table 4.11. These elements are used as simulation inputs for the Med Model software.

Table 4.11: Steps for defining Med model simulation inputs.

1	**Define Simulation Objectives**	Problems and decisions variables
2	**Define Locations**	Physical constraints and where events happen
3	**Define Entities**	Distinct types and classes
4	**Define Path Networks**	Movement by resources or entities
5	**Define Resources**	Human and non-human resources and their capacities
6	**Define Processes**	Important activities and how long they take
7	**Define Arrivals**	When and how frequently entities are introduced in the model
8	**Define shifts**	Daily and weekly shifts and breaks for resources and locations

4.7.3 Model Verification

As indicated in chapter three, the process of demonstrating that the model works as intended is referred to in simulation literature as model verification [52] to [58]. In our case, a thorough "walk-through" of the model inputs and the trace capability combined with screen messages and graphic animation that Med Model provides are used to verify the simulation models for the clinic and departments.

4.7.4 Model Validation

This step of the simulation process is meant to determine the degree to which the model corresponds to the real system. For establishing the validity of our model three approaches will be used for the validation of the model. These approaches were: (1) data validity, (2) computerized model verification, and (3) operational and output validation, they will be explored in detail in chapter five.

4.7.5 Conducting Experiments

This is the step where the simulation model is used to investigate why certain resource management rules or strategies are better than others. The use of "what if scenarios" in simulation allows assessing the impact of any potential changes on the service delivery system operation at each clinic and department without disruption and expense associated with trial and errors. In this step, decision input variables defining the model, which are independent, are manipulated or varied and the effect of this manipulation on other dependent or response variables are measured and correlated. In general, Med Model provides convenient facilities for conducting experiments, and running multiple replications.

4.7.6 Analyzing Output and Recommendations

As indicated in chapter three, output analysis deals with drawing inferences about the actual system based on the simulation results. Analyzing simulation output in our case depends on the initial objectives of building a simulation model for each clinic and department selected for this study. In addition, the ability of drawing correct inferences from the simulation output is essential to making system improvements.

Recommendations for improvements in the actual system are based on the results of analyzing the simulated model output.

For the purpose of this thesis, both the new modeling approach presented in chapter three and the methodology explored in this chapter will be used to model the health care delivery system in selected clinics and departments Zayed hospital as we will see in the next chapter.

Chapter 5

Modeling Results and Discussion

5.1 Introduction

This chapter discusses the results of the development of a simulation model for the selected departments and clinics using Med Model software for the purpose of assisting Zayed Hospital management in identifying bottlenecks and inefficiencies in the current health care delivery system. The model logic of the health care delivery system at the selected clinics and departments is described in section 5.2. Description of data used for model input is provided in section 5.3. Description of the assumptions that made the model operational is explored in section 5.4. Initiatives that have been taken to validate and verify the developed model are provided in section 5.5. Section 5.6 of this chapter explores in detail the strategies aspects of the model experimentation. In section 5.7, the significant assumptions and constraints that were applied to the model are discussed. Section 5.8 of this chapter presents the result of evaluation alternatives as a result of model experimentation. Also included are discussion and analysis of these results. In the last section of this chapter a summary of results is presented.

5.2 Model Logic

5.2.1 Emergency Department

The basic process logic for the simulation model of the Emergency Department (ED) starts with a patient arriving at the Emergency Department via ambulance or Helicopter and these are (EMS) patients, or walk-in patients. At this time, each of these arrivals is different up until the time a decision has to be taken to admit, observe, or discharge the patient. If a patient arrives via a car (walk-in patient), the patient first proceeds to the check-in desk where a registrar will quickly look over the patient and obtain patient identification information .If the patient appears unstable, a nurse will immediately place the patient in an available Exam/ Treatment (E/T) room. If the nurse should determine that the patient needs immediate care, it is possible for a patient to be expedited through the path of a patient arriving via ambulance. If this patient continues through the process designated for patients arriving via ambulance, the registration process takes place at the bedsides by a nurse. If the patient is stable and not considered to need immediate attention, the patient will go to the waiting room area and wait to be moved to triage by a nurse. Waiting patients are brought to the triage room according to their assigned priority. At this point in the process and after been triaged by a nurse, the patient is brought to the available Exam/Treatment room - there is a delay while the patient waits to be seen by the attending physician, at which time the physician and a nurse perform an initial assessment of the patient. At that time, the decision of ordering tests is made. If tests are required, there are, specifically, two types ordered within the ED, lab and x-Ray. If orders are needed, the patient will go to the radiology or lab department, and the amount of time spent depends on availability in these departments. Once all test results from both the radiology and laboratory are sent back to the E/T room, the physician can then make a diagnosis and decide to discharge, admit, or put the patient under observation. EMS (ambulance) patients are brought to the trauma room upon arrival, where a physician and a nurse quickly examine them. If x–ray is required, a nurse will use a mobile x-ray machine while patient is in the trauma room enabling them to then make diagnosis. At this point in the process, if EMS patients are to be put under observation they are kept in the trauma room until they are stable and can be discharged otherwise they are admitted. If discharged, the physician prepares the discharge and the patient is released to go home. If a patient is to be admitted a call is made to the department where the patient is to be admitted. Patients must then wait for an inpatient bed to become available before leaving the Emergency Department. At anytime, if a consultant is needed to examine a patient, he/or she is called and the attending physician who preformed the prior examination presents the patient. The consultant is then responsible for making the decision of admitting, discharging, or observing the patient. Process flow at the emergency department is shown in Figure 5.1. Generally, the emergency department service delivery process illustrated in the figure can be represented by the following set of processes. These processes occur in a sequential manner and some of the steps are either rearranged or omitted. (1) arrival, (2) registration, (3) triage, (4) initial assessment, (5) diagnostic testing (Lab & x-ray) (6) final diagnosis and treatments, (8) observe, and (9) discharge or admit.

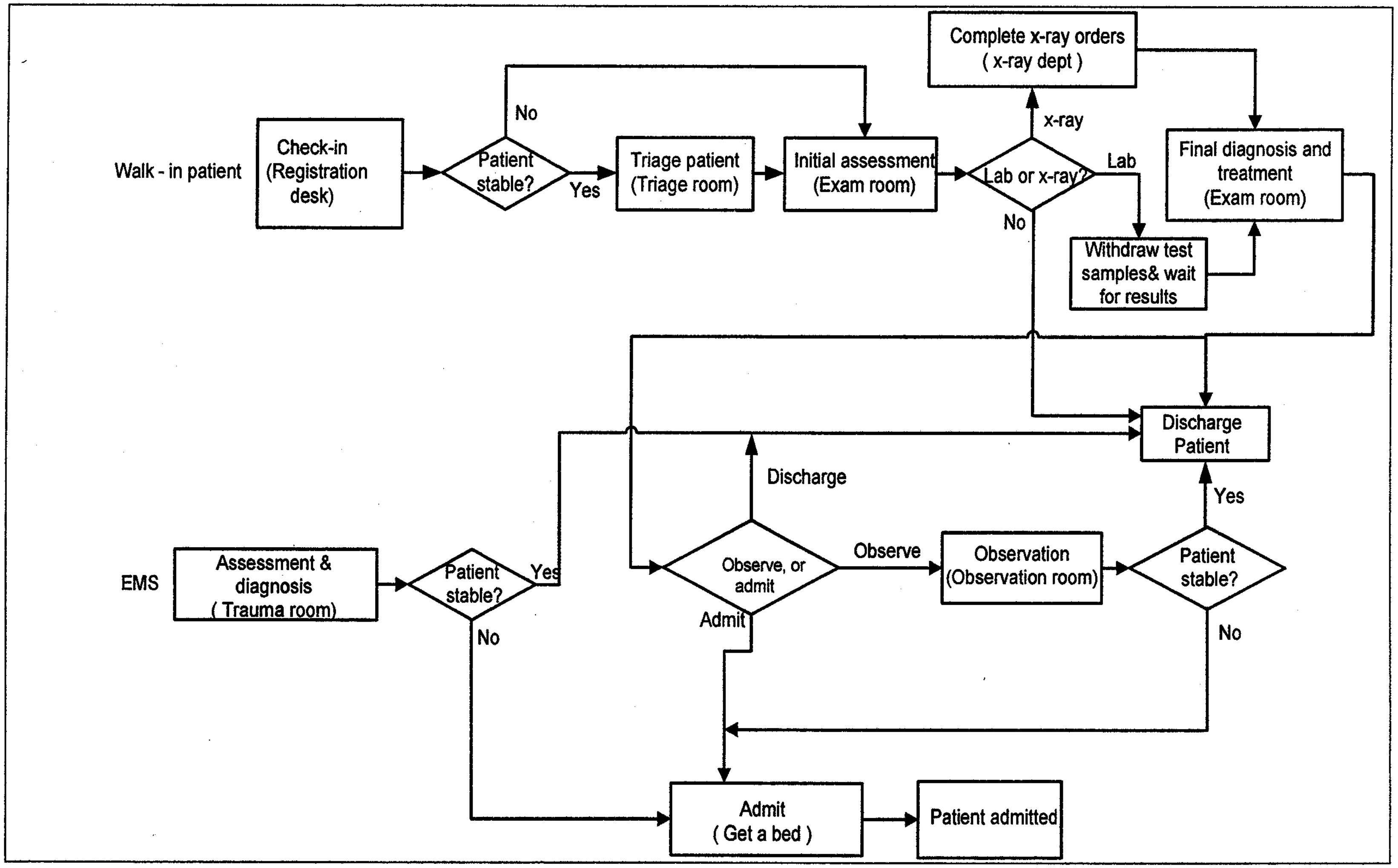


Figure 5.1: Emergency department process flow.

The emergency department maintains a constant staff schedule seven days a week for the whole year as shown in Table 5.1.

Table 5.1: Current staffing schedule at the emergency department

Shifts			
Resource	**Morning**	**Afternoon**	**Night**
	7AM - 2 PM	2 PM - 10 PM	10 PM - 7AM
Physicians	3	2	1
Nurses	6	4	4
Triage nurse	1	1	1
Receptionist	1	1	1

5.2.2 Family Medicine Clinic

The family medicine clinic schedules patients every 20 minutes during its 7 working hours. A hundred patients are expected to arrive in one day. The clinic is staffed by 2 receptionists, 7 doctors, 2 triage nurses and 4 assistant nurses. The clinic has a reception area, a waiting room, 2 triage rooms, and 7 treatment rooms. In addition to scheduled patients, walk-in patients seeking treatment at the clinic are accepted. This type of patient will have to wait for their medical files to be brought from medical records, a process that takes about (30 minutes +/-10). Patients enter the clinic and proceed directly to the registration desk where the two receptionists on duty register them. Registration generally takes about (3 minutes +/- 1) after which the patient goes to the waiting room where he or she waits to be taken to the initial assessment (triage) room. A nurse then escorts the patients to the initial assessment room as soon as she and the initial assessment room are available. In the initial assessment room, the nurse spends about (5 minutes +/- 2), takes the vital signs and triages the patient preparing him or her to see the doctor. Once the nurse has prepared the patient, a doctor assisted by a nurse examines the patient for (20 minutes +/-5). At the conclusion of the examination some patients leave the clinic. Others, who require lab tests or x-ray procedures for completing the diagnosis and treatment, are sent to the lab and x-ray departments following the doctor's examination. When lab tests and x-ray procedures are completed, patients return with results to the clinic and wait for final diagnosis and treatments. A doctor then diagnosis and treats the patient for (15minutes +/-5) as soon as he or she and the exam room are available. Then the patient leaves the clinic. The initial assessment, exam, and treatment times vary by patient type and the seriousness of the case. The clinic process flow is shown in Figure 5.2.

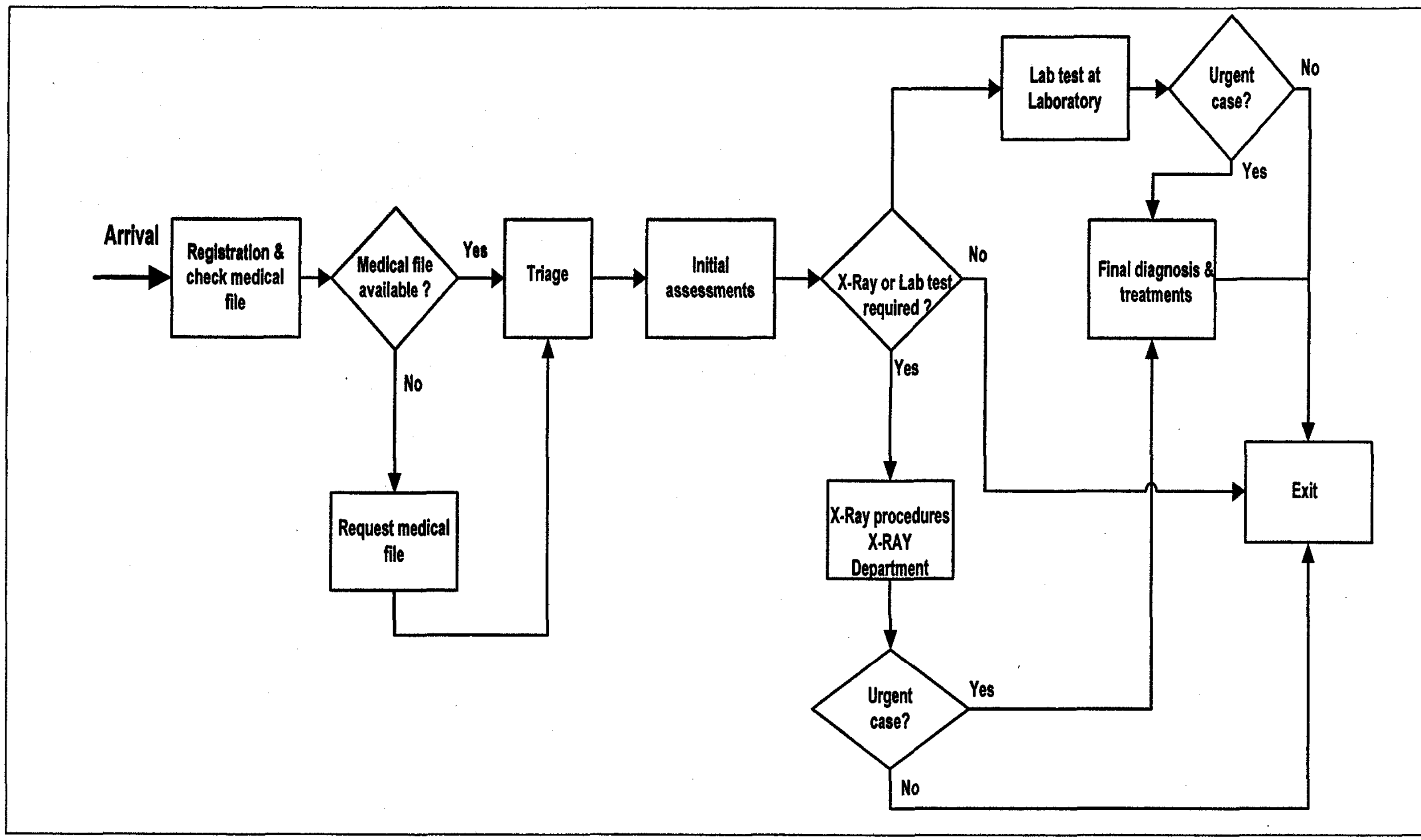


Figure 5.2:- Family Medicine Clinic Process Flow.

5.2.3 Ortho Clinic

The orthopedic clinic at Zayed hospital operates from 7:30am to 2:30pm five days a week. During the normal operating hours, the clinic receives about a hundred patients. There are two types of patients at the orthopedic clinic: Pre-scheduled patients who are scheduled every 30 minutes and represents the majority of the overall clinic patients and walk-in patients who represent about 25-30% of the over all clinic patients. The clinic staff consists of 2 receptionists, 1 appointment clerk, 7 doctors and 5 nurses for assisting doctors. The clinic has a reception, a waiting area, 7 exam and treatments rooms, and 1 special procedures room. Upon arrival at the clinic, the patient proceeds to the registration desk where a receptionist checks the availability of the medical file and registers the patient. The registration process takes about (3 minutes +/-1) in normal cases after which the patient goes to the waiting room where he or she waits to be taken to the exam/treatment room. In the case of walk-in patients medical files have to be requested from medical records, a process that takes up to (30 minutes +/-10). Once the doctor and the exam/treatment room are available a nurse escorts the patient to the exam/treatment room. This first encounter with the doctor includes the initial assessment of the patient, which takes about (20 minutes +/-5). At this point, patients that do not require special procedures or x- ray tests leave the clinic. Patients that require special procedures are sent to the special procedures room depending on the availability of the room and technician. In the special procedures room, a technician performs the required procedure such as casting or removal of metal, which takes about (15 minutes +/-5). Once the patient has completed the special procedures required, a doctor will check the patient for (5 minutes +/-2) then patient leaves the clinic. Patients that require x-ray procedures go to radiology

radiology following their first encounter with the doctors. After completing the x-ray procedure, they return back to the clinic for their second encounter with the doctor for treatment. This process takes about (10 minutes +/-5). Some of these patients leave the clinic, others are sent to the special procedures room to complete their treatment process and then exit the clinic. Process flow for the clinic is shown in Figure 5.3.

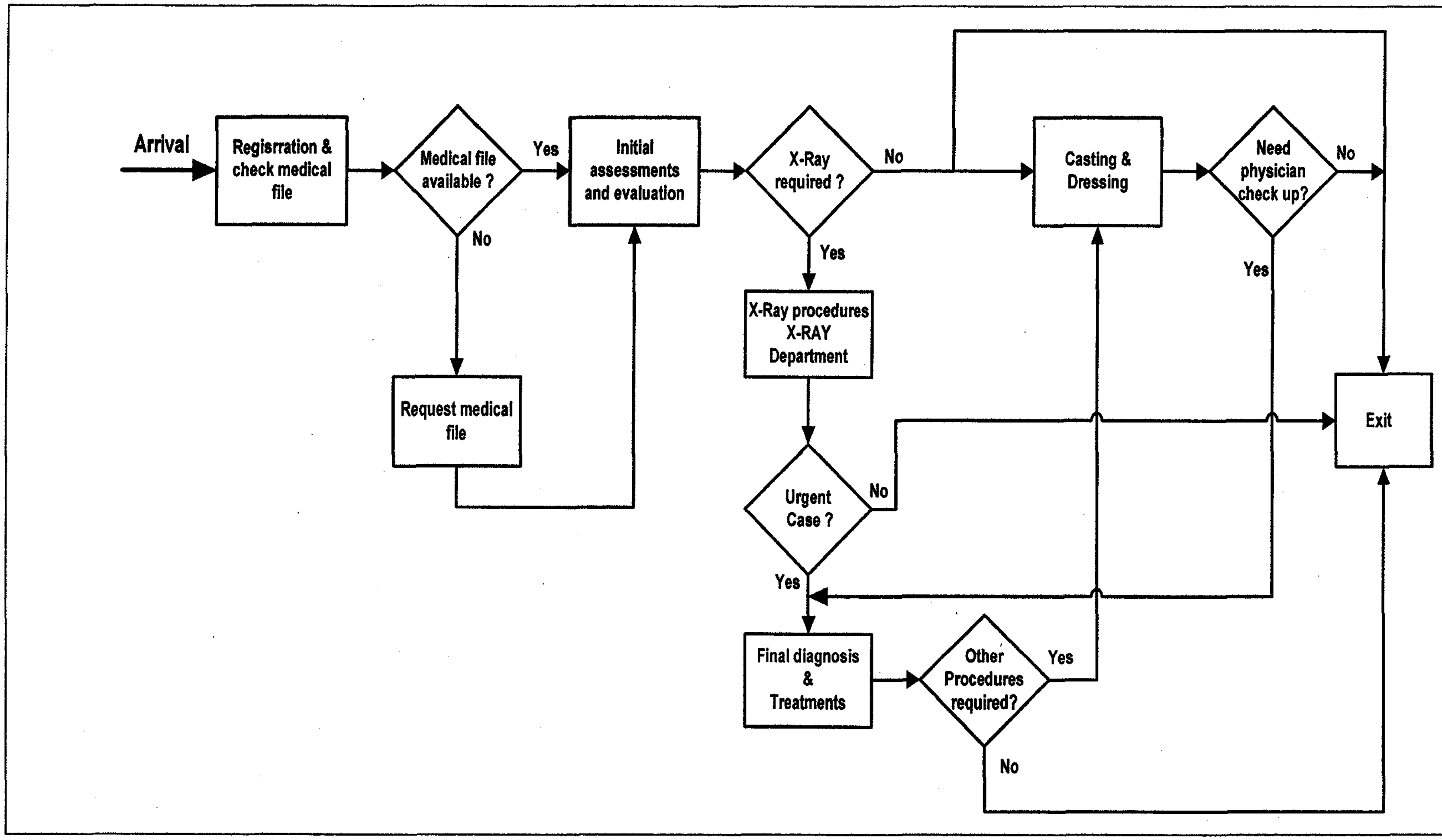


Figure 5.3: Orthopedic clinic process flow.

5.2.4 Diagnostic departments

5.2.4.1 Radiology department

The main radiology department at Zayed hospital contains seven exam/procedure rooms. Examinations performed include plain film (normal x-ray), special procedure, ultrasound mammography, CAT scan, and MRI. The primary patient base is imaged Saturday through Wednesday, from 7:30am-2:30 pm. During the evening hours 2:30 pm - 9:30 pm, two radiographers are on staff to support inpatient services and emergency unit referrals. One radiographer fills the nightshift from 9:30pm -7:30am. During weekends and holidays, two radiographers are on staff during the daytime, two during the evening, and one at night, with a radiologist on call at all times. Recently, the department has extended the MRI working hours until 7:30 pm during weekdays only. These extended hours are used to accommodate the increasing demand for MRI procedures. Ultrasounds, CAT scans (CT), special procedures, and MRI, are all pre-scheduled. To schedule an exam the patient must come to the department with an exam requisition form indicating the type of the exam that needs to be performed. A receptionist will keep a logbook of the names of patients expected on specific day. Similarly, walk-in patients needing radiology examinations will bring requisition forms from the referring clinics to the radiology department. The receptionist will log patient information into the daily logbook and will go to the film library to access the family folder in order to pull prior films to be used for comparison. Walk-in patients are asked to wait in the waiting rooms until an appropriate exam/procedure room and radiographer becomes available. These patients are imaged on first- come, first-served basis. For inpatients, the nurse in charge of the patient takes the requisitions to the radiology department in order to determine the earliest day on which the patient may be imaged. The receptionist will enter the patient information and proposed date in the same logbook in which pre-scheduled outpatient procedures are recorded. On the day of the scan, the nurse brings the patient to the department at the time when the exam/procedure room and radiographer are available for imaging. Emergency cases are given priority over all patients and are imaged immediately. Process flow at the radiology department is shown in Figure 5.4.

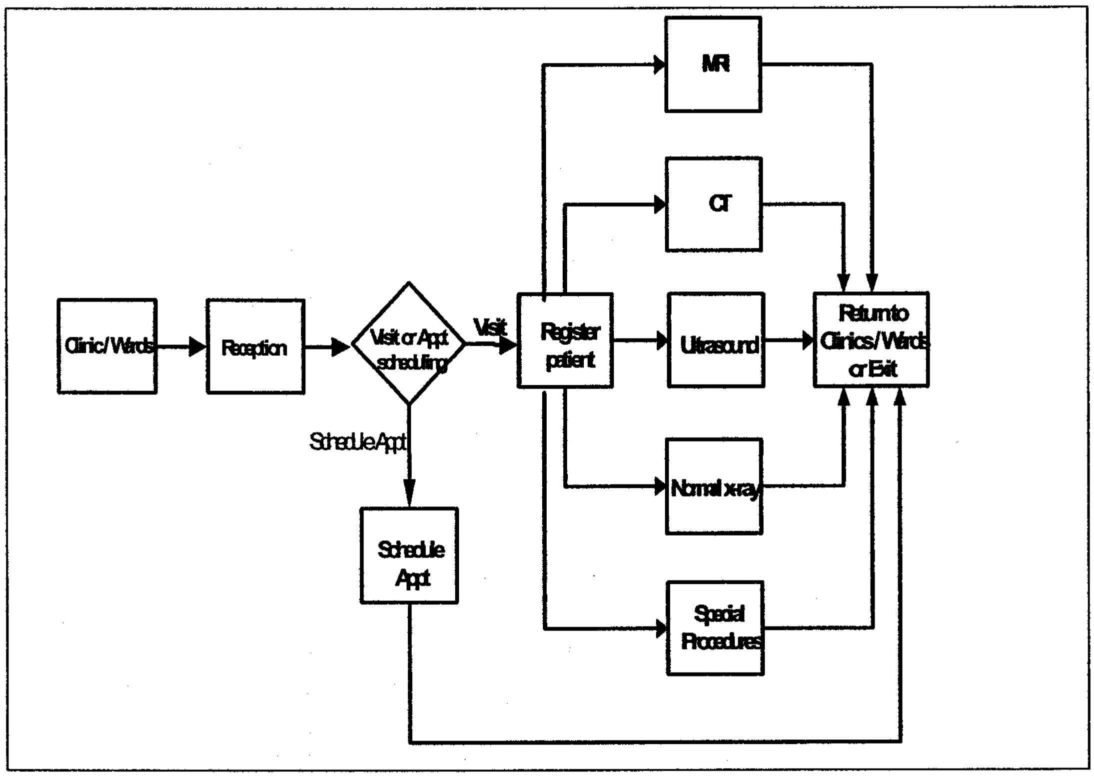


Figure 5.4: X-ray department process flow.

5.2.4.2 Laboratory

Zayed hospital laboratory department is comprised of multiple disciplines within the field of pathology and laboratory medicine and performs a large array of routine and main tests on a 24 hour, 7 days per week basis. For the purpose of aiding physicians with information for diagnosis, prevention and/or treatment of any disease, the laboratory is sub-divided into a number of divisions namely: biochemistry, hematology, serology, microbiology, blood bank, histopathology, polymers chain reaction (PCR), special chemistry, and Phlebotomy. The laboratory performs more than 400 tests in these different divisions. It also monitors and support several satellite clinics which vary in size and range of tests. The following steps best describe sample processing at the laboratory:

1. Sample collection
2. Sorting and dispatching
3. Processing
4. Analysis and interpretation
5. Reporting of test results

Patients from outpatient clinics and emergency department are sent to the laboratory reception area with their test requisition forms. At reception, a receptionist checks that all patient information and clinical data are filled clearly out in order for it to be accepted for processing. This process takes about (3 minutes +/- 2). In cases where the requisition form and samples are being delivered from the wards, the sample is also checked for the correct corresponding ID number and name. Patients are then sent to the phlebotomy to have the appropriate sample drawn or to be issued with a stool/urine container, which takes about (5 minutes +/- 2). Samples and requisition forms are then sent to the receptionist to be dispatched to their respective divisions. At each division a technician ensures that it is the correct sample for the requested test and then takes about (5 minutes +/- 2) to prepare the sample for processing. Processing time depends on the urgency of the case. In general, routine specimens take 40 minutes to 3 hours depending on the type of test. Urgent test requests take (30 minutes +/- 10). When processed and completed, requests and results are sent back to the reception and to the clinics or wards. A flow chart representing the process flow at the laboratory is shown in Figure 5.5.

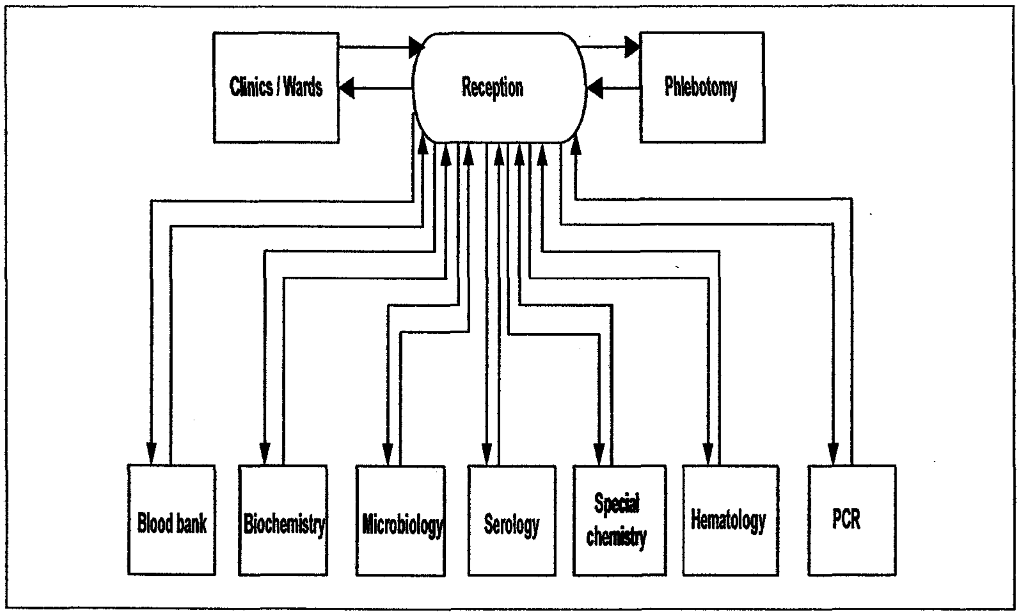


Figure 5.5: The flow of clinical samples at the laboratory.

The laboratory records and equipment manual were used to analyze the workload at each division at the laboratory. Of interest is the biochemistry division accounting for about 45% of the total laboratory workload. The workload includes tests such as Albumin, Alkaline Phosphate, Calcium, Cholesterol, reactive protein, Creatinine, Electrolytes, Glucose, and etc. The average turnaround time for these tests according to the laboratory records was found to be about 35 minutes. The special chemistry division accounts for 22.3 % of the total workload and the hematology division accounts for 10 %. The average turnaround time at both the special chemistry and hematology was about an hour. The average number of tests per month at the laboratory is shown in Figure 5.6.

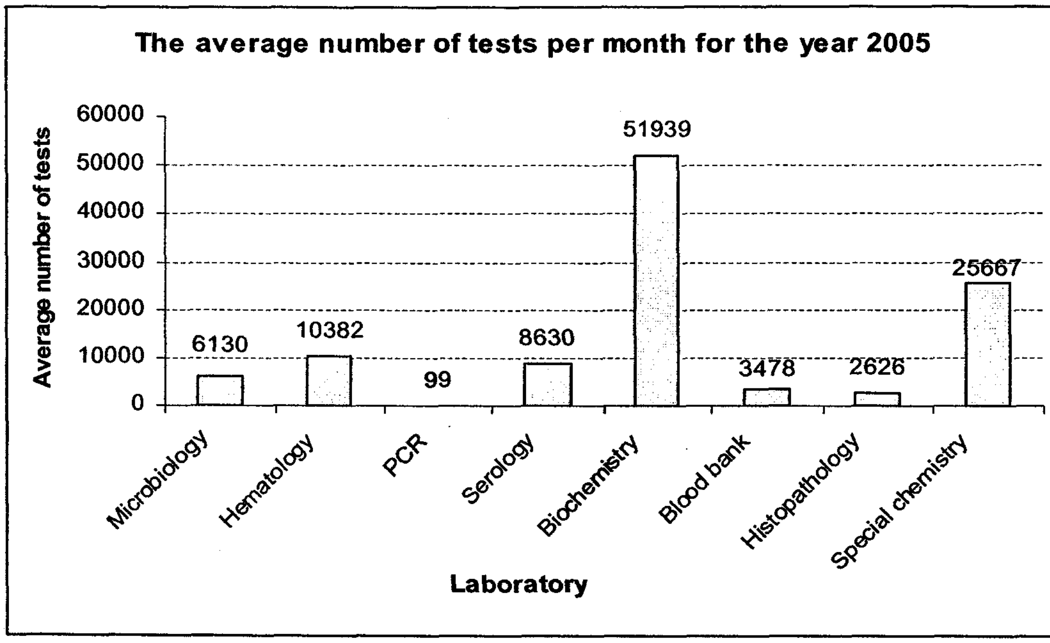


Figure 5.6: Number of tests per month at laboratory for the year 2005. (Source: hospital records).

5.3 Preparing Model Inputs

The modeling process for the selected clinics and departments at Zayed Hospital has been undertaken using Med Model 6.2 simulation package. As indicated previously, Med Model is a window-based software combining the functionality of high-level simulation software with extensive coding capabilities. It supports the entire process of the simulation development cycle, including model building, data analysis, output analysis, and animation. In building the simulation model it was important to ensure that sufficient data has been compiled to define the basic operational aspects of the delivery system at the hospital. With the goal of building a valid representation of the defined system operation, the simulation model was designed to reflect the service delivery logical processes in the selected departments and clinic described earlier in section 5.2. For building the simulation model, simulation steps described in Figure 2.9 in section 2.7

were adopted. The proposed modeling approach described in chapter three was used to model the service delivery system at the selected departments and clinics. The first step was to define the purpose of the simulation model. The previously described problems of long waiting time and service quality problems, resource shortage, provided the starting point for the development of the simulation model. Patient and staff satisfaction survey results served as the main driver for the model development. Many staff voiced concerns about workload because of staff shortages and the unavailability of certain resources to achieve their daily tasks. The analysis of data form surveys was used to determine areas of concerns as indicated earlier. Additionally, informal interviews of staff were conducted to gather their perception of the delivery system operation. A list of problems impeding clinic efficiency was compiled as a result of these interviews. These problems include staff scheduling, workload, and shortage of resources.

The purpose of developing the simulation model was to support resource deployment to improve service time and aid strategic decision-making in resource management in the selected departments and clinics. Additional data for building the simulation model was collected on patient load, patient arrival rates, types of treatment processes, staff schedules, waiting times at various stages, sequence and time required for each process associated with treatments. Some of this data was collected by interviewing staff. Other data such as service demand was collected from the hospital records. Process evaluation forms and direct observation with the judgment of staff directly involved in the service delivery operations were used to identify process and activities, derive average processing times, determine the time and frequency for patient arrivals, and to represent the interactions between the different service delivery processes. Other elements including treatment locations, pathway networks for patient and dynamic resources, patient processing and routing logic were added.

5.3.1 Determining Queue Structure and Discipline

One important aspect of the modeling process was to determine the queue structure and discipline at the selected department and clinics. In doing so, interviews with staff and administrators at these clinics and department were conducted. Moreover, observation of the system was used to define queues. Results reveled that at each server in each clinic and department there was a single queue with first in first served discipline. The exception to this case is the arrival of EMS patients at the emergency department. EMS patients have priority over other patients.

5.3.2 Determining Arrival Time

As indicated previously, during the review of hospital records and statistics it was found that no records concerning the patient and inter-arrival had been kept by selected departments and clinics. Only records of total number of patients at these clinics and departments existed. Therefore, the total number and arrival time of patients were observed and recorded for a period of 3 weeks at each of the selected departments and clinics using the process evaluation forms described in chapter four. The arrival data then was analyzed on an hour basis during a working day. Moreover, this data was used to calculate the mean inter-arrival for each of the working hour interval of the day for the corresponding population level at each selected department and clinic. To best demonstrate this process, the arrival of patients at the emergency department is given here as an example. First data was segregated by the hour of the day for patients as shown in Table 5.2. Patient arrival was further divided into percentages of patients for each hourly segment of the day as shown.

Table 5.2: Emergency Department Hourly Arrival Cycle.

Period	Actual time of the day	Average arrival	Proportion of The total arrival
1	6:00-6:59	2.40	0.016
2	7:00-7:59	3.50	0.024
3	8:00-8:59	5.00	0.034
4	9:00-9:59	11.9	0.081
5	10:00-10:59	6.80	0.046
6	11:00-11:59	11.5	0.078
7	12:00-12:59	5.60	0.038
8	13:00-13:59	3.80	0.026
9	14:00-14:59	6.80	0.046
10	15:00-15:59	11.5	0.078
11	16:00-16:59	7.90	0.054
12	17:00-17:59	13.0	0.088
13	18:00-18:59	8.90	0.060
14	19:00-19:59	12.1	0.082
15	20:00-20:59	9.10	0.062
16	21:00-21:59	7.60	0.052
17	22:00-22:59	8.10	0.055
18	23:00-23:59	2.10	0.014
19	0:00-0:59	4.40	0.030
20	1:00-1:59	2.70	0.018
21	2:00-2:59	0.90	0.006
22	3:00-3:59	0.90	0.006
23	4:00-4:59	0.40	0.003
24	5:00-5:59	0.40	0.003
Total		147.3	1

Staff interviews and emergency logs and records were used to analyze the EMS patient arrival process. The EMS inter-arrival time was fitted to an exponential distribution as shown in Figure 5.7. The number of patients at each arrival instant was best fitted by a triangular distribution. Interviewing emergency staff reveled that the maximum number of EMS patients at one arrival could not exceed four patients. The average total number of EMS patients during a day was verified by reviewing the emergency logs and records.

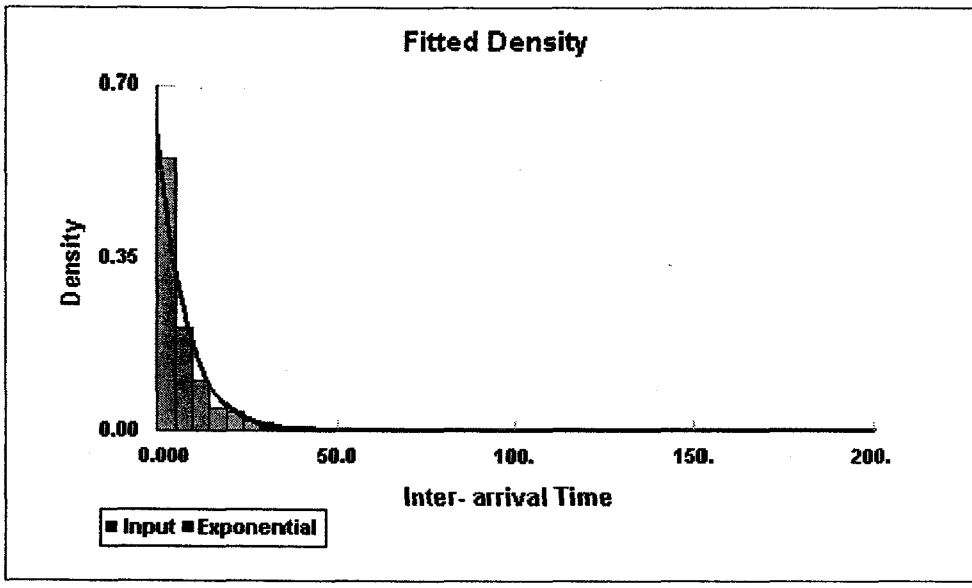


Figure 5.7: EMS patient inter-arrival time distribution.

At the diagnostic departments (laboratory and x-ray), the arrivals from other outpatient clinics and inpatient wards that are out of the scope of this study were modeled as separate arrivals from the arrival of the selected outpatient clinic and emergency. This was important to account for the total patient arrivals at the two diagnostic departments in a working day. These arrivals were modeled as external arrivals.

5.3.3 Determining Service Time Distribution

Similarly, there were no records kept concerning the processing time (service time) at Zayed hospital. For the purpose of estimating the service time encountered by patients at each clinic and department under-study, data were collected using the process analysis forms attached to each patient file. Hundreds of patient processing times were recorded and analyzed during their visits. Results then were used to estimate service time distribution for each process at each department and clinic. As part of its data analysis capability, Med Model includes a stat fit as a tool for fitting appropriate statistical distributions to input data. Stat fit was used to fit process time to its proper disruption and then the Kolmogorov-Smirnov goodness-of-fit was used to test the correctness of the chosen distribution for each process. Example of determining service time distribution for the initial assessment and final diagnosis are shown in Figures 5.8 and Figure 5.9 respectively.

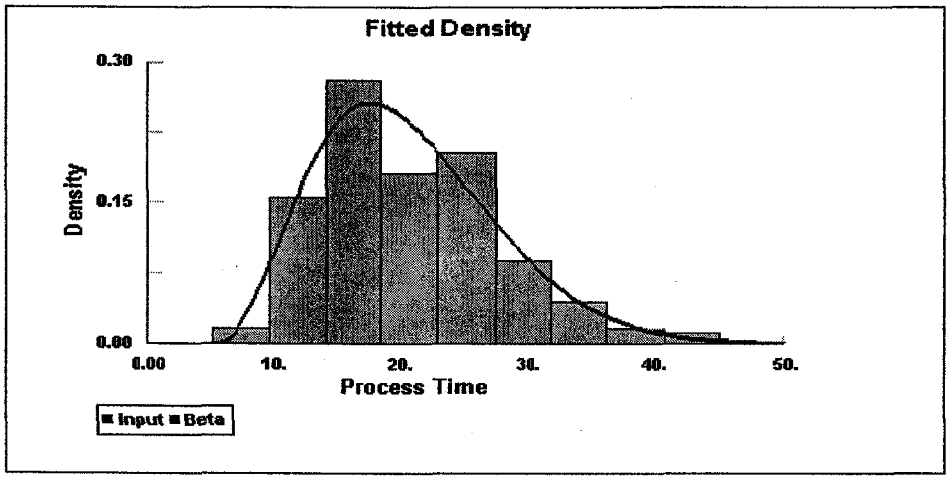


Figure 5.8: Initial Assessment time distribution-Emergency Department.

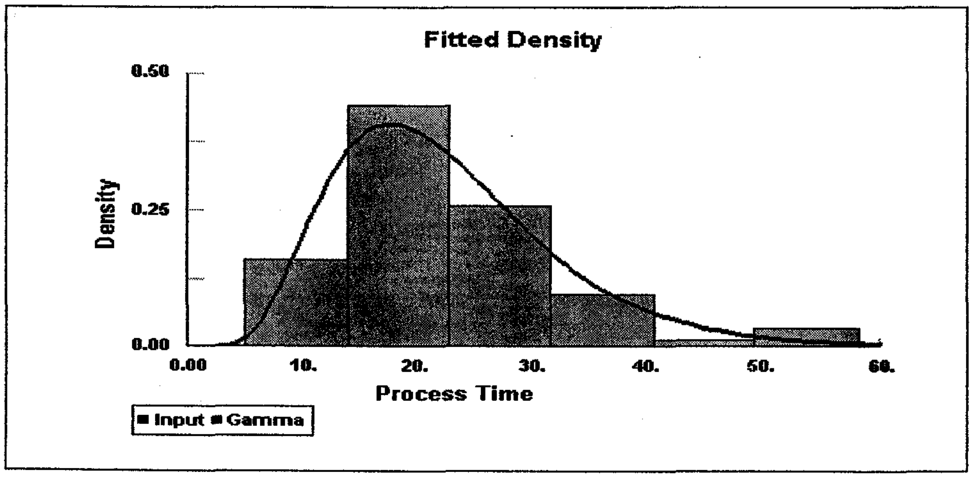


Figure 5.9: Final diagnosis time distribution- Emergency Department.

Determining service time distributions and the laboratory processes was a complex task. First, the technician's involvement in processing samples tests was found to be minimal compared to the total processing time and turnaround time. This involvement was mainly to prepare samples and report results when tests are finished. The total turnaround time depends mainly on the equipment used for analyzing test samples. Equipment has different processing time and capacity depending on the type of the analyses required for tests. Additionally samples are analyzed simultaneously. So sample processing starts only when a certain number of samples is available for processing. This was difficult to model because of the large number of tests and equipment at the laboratory. Adding to this complexity is that patient can request more than one test at different laboratory divisions. This was difficult to account for in the modeling process. Therefore, it was decided to model the laboratory processes based on the average processing time for each laboratory division. This average processing time mainly represents the test of high demand at each division. Reviewing the laboratory equipment manuals and test turnaround records at the laboratory validated the average processing time. Moreover, tests with turnaround time more than two hours are not modeled since they do not represent patients from the department and clinics under study. These patients normally are sent home after scheduling an appointment at the clinic. Emergency and family medicine patients are mainly sent to biochemistry, hematology, and microbiology department divisions.

An example of a typical simulation parameters and distributions for the emergency department simulation inputs is given in Table 5.3.

Table 5.3: Emergency Department Simulation input Parameters.

Locations Name	Capacity	Rules for Selecting Entities	Downtime
Registration desk	1	Oldest by priority	None
Queue waiting	1	Highest attribute for X-ray& Lab	None
Triage room	2	Oldest by priority	None
Exam room	4	Random	None
Trauma room	3	Oldest by priority	None
Observe room	3	Oldest by priority	None
Waiting room	Infinity		

Entities

Walk-in

EMS patient

Resources Name	Number	**Shifts** Morning	Afternoon	night
Physician	6	3	2	1
Nurse	14	6	4	4
Trauma Room	3			
Observation Room	3			
Examination Room	4			
Receptionist	3	1	1	1
Triage nurse	3	1	1	1

Processes Name	Location	Resources required & quantity	Process time distribution
Registration	Reg. Desk	Receptionist (1)	T (2, 3, 4)*
Triage	Triage Room	Triage Nurse (1)	B (1, 8, 4.61, 5.12)**
Initial Assessment	Exam Room	Physician(1) & nurse (1)	B(5, 84.4, 3.65, 15.5)
Final Diagnosis& Treatments	Exam Room	Physician(1) & nurse (1)	G(5,86.4, 3.64,15.5)^
Observation/Prepare	Observe Room	Nurse (1)	T (10, 15,20)
Observation process	Observe Room	/	T (20,45,120)
Prepare Patient (finish)	Observe Room	Nurse (1)	T (2,3,5)
Trauma Diagnosis& Treatments	Trauma Room	Physician(1)& nurse (1)	T (45,60,120)

Arrivals	Inter-arrival	Quantity Each
Walk -in	1440(MIN)	Normal (147,2)
EMS	Exponential (550)	Triangular (0,1,4)

*Triangular Distribution (min, mode, max), **Beta distribution (min, max, p, q),

^ Gamma distribution (min, alpha, beta).

5.4 Modeling Assumptions

In an effort to simplify the model development process and to achieve a higher degree of realism in representing the health care delivery system at the selected clinics and departments, it was essential to make some significant assumptions related to the operational aspects of the delivery system. Direct interviews with staff and administrators and direct observation of the delivery system were used to validate these assumptions. The following assumptions and constraints were applied to the model to represent the rules controlling the simulations:

- Patients remain in clinic/or department during their entire stay except when going for lab work or x-ray;
- All emergency patients retain their same acuity level assigned to them during triage;
- Staff will complete treatment on a patient before performing another task; the exception to this case is the arrival of EMS patients. EMS patients have priority over other patients;
- Staff breaks are not modeled for all selected clinics and departments;
- There is no downtime assigned for locations and resources;
- At outpatient clinics, patients with appointments have the priority over walk-in patients;
- Appointment patient medical files are brought to the clinics an hour before clinic working hours;
- Bringing medical files of walk-in patients is a task performed by medical records staff.

- Patients returning from laboratory and x-ray department have the priority over other patients;
- In the case of a patient requesting more than one test at the laboratory department the patient waits the longest turnaround time;
- Patients admitted are considered exiting the system;
- Emergency and family medicine patients are mainly referred to biochemistry, hematology, and microbiology divisions at laboratory,
- Simulation results are rounded to the nearest integer, and
- For human resource working time a fraction of day time is allowed.

5.5 Model Verification and Validation

As descried in an earlier chapter, verification is the process of ensuring that the model is running as a representation of the real life system and as it is expected it to run. Both model verification and validation are essential in the development of the simulation model and in deriving areas of improvements. For the purpose of this research, the verification and validation process was achieved in a variety of steps through the model building process to ensure the model credibility. Contributing to the success of this process was the involvement of different staff levels at the early stages of model building. This facilitated the capture and translation of reliable, relevant, and accurate data for the service delivery system in the selected departments and clinics. Furthermore, staff interviews and direct observation during a month-long period provided the right level of detail so that no component of the operational aspects of the service delivery system was missed. Reflecting on the above, three approaches were used for the validation and verification of the model. These approaches were: (1) data verification, (2) computerized model verification, and (3) operational and output validation, they will be explored in detail next.

1. Data verification

This process involved ensuring that the collected data for the modeling purposes are valid. In doing so, the collected data that best described the operational aspects of the service delivery system at the selected departments and clinics was compared to the hospital records and statistics when available. Additionally, the structured process flow chart for each clinic and department was reviewed with staff and administrators to ensure that it was a determination of the appropriate levels of detail that best described the operational aspects of the health care delivery system at these clinics and departments. Few errors related to process flow and patient flow at the emergency and family medicine clinic were identified and corrected. Also, some errors were found related to resource assignment in the radiology department. The identification of these errors at early stages of model development helped in redesigning the process evaluation forms used for collecting data. The collected data involved the following types:

- Total number of patients arriving at each clinic and department
- Number of patients in each arrival
- Frequency occurrence of each arrival
- Capacity and number of servers in each clinic and department
- Resources required to provide services
- Process duration time (service time)

2. Computerized model verification

This type of validation is defined as assuring that the model program coding and the conceptual model structure is correct for the purpose it is intended to. Using the animation capability of the Med Model software the model logic was checked and verified. Animating the simulation model provided a visual corrective technique for ensuring patient flow through the system for possible modeling errors. Patient flow from arrival time to departure time in each clinic and department was checked. Additionally, the trace capability of Med Model to find and fix model errors was used. Examples include the Run/Check option, and screen messages. Traces of logic and routing were printed and compared to the process flow charts during the data collection process. All relevant variables including entities, resources, locations, staff path networks, patient path networks were represented in the model. Therefore, the simulation model for the selected clinics and department found to be a correct logical representation of the real health care delivery system at the clinics and departments.

3. Operational and output validation

The operational and output validation deals with determining whether the model output behavior is accurate for the purpose it intended to. This type of validation can only be conducted when the model is made operational. In using this type of validation to ensure that the model developed is a valid model it was decided to monitor an important overall performance measure, the average length stay (LOS) at the selected departments and clinics. As discussed earlier, average length of stay (LOS) is the sum of process time (service time) and waiting for resources. The simulated average length of stay was then compared to the collected average length of stay during the observation period. In doing so, the first step was to execute the model under the current hospital staff scheduling and available resources for 50 replications, each of one month in duration. Warm-up periods of 1 day were used for each replication to allow for the system to reach realistic operating conditions before collecting appropriate statistics. Additionally, a 95% confidence interval was computed for the 50 replications. The results of comparing the collected average (LOS) to the average simulated (LOS) are shown in Table 5.4. The lowest collected average (LOS) was 30 minutes for normal, special procedure, and ultrasound patients at the radiology department and highest collected average (LOS) were for EMS patients at the emergency department. These collected (LOS) averages are compared to averages simulated (LOS) of 38 and 137 minutes respectively.

Table 5.4: Model Validation Results.

Department/Clinic	Collected Average (LOS)(MIN)	Average Simulated (LOS)(MIN)	Average Simulated (LOS) (MIN) with 95% C.I. Low-High
Emergency			
Walk-in Patient	101	104	102- 107
EMS Patient	140	137	134 - 139
Family Medicine	89	86	85 - 87
Ortho Clinic	72	78	77 - 79
X-ray Department			
CT SCAN Patients	52	58	57 - 59
MRI patients	55	63	63 - 65
*Other patients	30	38	36 - 39
Laboratory	60	54	54 - 55

*Normal X-ray, Special Procedure, and Ultrasound

Reflecting on the above, the simulation model for the selected clinics and departments was found to be a correct logical representation of the real health care delivery system at the clinics and departments.

5.6 Model Experimentation

Designing experiments for the purpose of modeling a health care delivery system is not an easy task. Several system variables have to be accounted for in the modeling process if the model were to be successful in achieving predetermined objectives. In an attempt to aid the decision of designing experiments using simulation modeling, Conway[153] identified two levels of planning (1) strategic planning and (2) tactical planning. Strategic planning includes identifying the factors that best describe the delivery system operations to be incorporated in the simulation, the level at which each factor is evaluated, and the output performance measure. Tactical planning involves a decision on how the simulation runs are executed. Clark[154] classified the variables that should guide the modeling process in simulation modeling into four categories including: Policy variables, Stochastic variables, System parameters, and Performance measures. Policy variables include strategic variables such as: scheduling staff, and service disciplines. Stochastic variables include the following:

- Number of servers within the clinic;
- Queue's structure and discipline;
- Number of queues for each server;
- Arrival and inter-arrival time;

- Demographic of calling population; and
- Patient treatment time distribution.

The third category, system parameters includes variables such as facility structure. The fourth category includes system output variables that should be monitored and analyzed. These include patient total time in the system, resource utilization, and patient waiting time for a resource.

Clearly, if all the above category variables were to be investigated and analyzed, considerable data, and data analysis would be required. For the purpose of identifying the most critical variables to be used to guide model experiment design in this research, it was decided to account for variables that best represented management, staff, and end-user concerns. Bottlenecks and inefficiencies within the delivery system, determined during direct system observation and staff and management interviews, helped in selecting experiment variables. The following variables were selected for the analysis of this research:

- Number of patients at each clinic
- Level of staffing at each clinic
- Number of servers at each clinic; and
- Staff scheduling policies and timetables.

5.7 Output Performance Measure

In order to assess the effectiveness of the system output in representing the real system, certain performance measure statistics for the model were collected and analyzed. It was decided to monitor main outcome measures including the average length of stay (LOS) and staff utilization values at each of the selected clinics and departments. Furthermore, these measures were of main interest to management, patients, and staff. The output these measures provided the information needed to decide upon possible solutions for solving problems related to the length of stay, resource utilization, and workload at the selected departments and clinics. Following is a list of performance measures used for this study:

- total patient length of stay (LOS) from registration completion to discharge;
- patient average waiting time for a resource;
- patient average time in operation (processing time);
- resource utilization rate at each clinic and department; and
- number of patients in queue at each process;

5.8 Evaluating Alternatives Results and Discussion

As indicated earlier, the care delivery process in the health care setting in general requires identifying effective and ineffective resource management methods and procedures. Long patient waiting times and an increasing demand for quality of health care services as described before are long lasting problems that have drawn the attention of many health care research studies.

In order to evaluate the current situation in the departments and clinics properly and to determine the optimal solution(s) for the concerns that management and staff identified relating to resource utilization and patient length stay (LOS), different scenarios pertaining to the operations of the health care delivery system at the selected departments and clinics were developed and evaluated. As emphasized earlier, the performance measures included the total length of stay (LOS) of the patient as he/she goes through the care delivery process, and the utilization rate for resources (human and non-human) in these departments and clinics. Statistics of the previously described performance measures at these clinics and departments were compared for different scenarios of different operations strategies to improve patient throughput, access, and resource utilization.

The following scenarios pertaining to the operations of the health care delivery system at the selected departments and clinics were created for proper course of actions once the baseline model was verified and validated:

- Current system operation (baseline model);
- Change staff levels and working hours at the emergency department;
- Change staff level and working hours and introducing an electronic patient medical records at all departments/ clinics
- Population growth (increased demand)

The objectives of developing these scenarios are to decrease the (LOS), and maximize staff utilization within a certain range. Templin [155] claimed that in most health care organizations the target resource utilization should be in the 70% to 80% range. For the purpose of model experimentations, this range was selected as the target utilization range when analyzing the model output. Different staff-scheduling policies were input into the current system for experimentation purposes in an attempt to overcome the resource under/or over utilization problem and reduce (LOS) at the selected departments and clinics. These new policies varied on the number of physicians and nurses and in some, the shift duration was changed. Fifty replications of the model for each of the scenarios as well as the current system were run, with each replication consisting of 30 days plus one-day warm-up period. A 95% confidence interval is computed for each scenario as well as the current model.

5.9 Current System Operation

5.9.1 Average Length of Stay

Long patient waiting times and increasing demand for quality of health care services are long lasting problems in health care delivery system. Results of running the simulation model under the current resource management practices at the selected departments and clinics are shown in Table 5.5.

Table 5.5: Simulated average (LOS) for the current system.

Clinic	Avg (LOS) (MIN)	Avg Time In Move Logic (MIN)	Avg Time Wait For Resource (MIN)	Avg Time In Operation (MIN)	Average (LOS) 95 % C.I. Low-High (MIN)
Emergency					
Walk-in	104	3	63	38	102 - 107
EMS	137	1	26	110	134 - 139
Ortho clinic	78	4	26	48	77- 79
Family clinic	86	2	27	57	85- 87
X- ray *	38	1	23	14	36 - 39
CT	58	1	30	27	57- 59
MRI	64	2	15	47	63 - 65
LAB	54	1	18	35	54 - 55

* Normal x-ray, Ultrasound, Special procedure

The average (LOS) is indicated by the entries in column (2) of this table and is the sum of the entries in columns (3), (4), and (5). Entries in columns (3), (4), and (5) represent average time the patient is in move logic, average time the patient waits for a specific resource, and average time the patient is in the operation respectively. For walk-in patients at the emergency department, the average (LOS) is 104 minutes with 60 % of this average (LOS) found to be a waiting time to secure resources. On the other hand, EMS patients encountered an average (LOS) of 137 minutes, with 80 % of this time representing services performed. At the orthopedic clinic the patient average (LOS) is 78 minutes; and at the family clinic the average (LOS) is 86 minutes. Part of the patient average (LOS) at both family medicine and orthopedic clinics is a waiting time for their medical file to be brought to the clinics in the case of walk-in patients and the time required for x-ray procedures and lab tests when referred to other diagnostic departments. The results of analyzing the average (LOS) for the current system set the stage for the essential need for improvement at the clinics and departments.

5.9.2 Resource Utilization

Running the baseline model with the current resource assignment at the selected clinics and departments yields the results shown in Table 5.6. At the emergency department all but the afternoon and night shift physician resources are underutilized. This was due to the high patient demand during both shifts. The case is similar in both the family and orthopedic clinics. All resources are underutilized with the exception of the technician at the orthopedic clinic. The technician utilization rate is 70% and is within the target utilization rate of 70%-80%. At the x-ray department during weekdays, the normal x-ray technicians at the morning and night shift, MRI technician, CT nurse, and CT technician are all within the target range utilization rate of 70%-80 %. On the weekend shift, technicians on the morning and afternoon shift are underutilized and the utilization rate for the technicians on the night shift is 73%. At the laboratory, the minimum involvement of technicians for the processing of samples and the lower workload at the hematology and microbiology are the main reason for this underutilization. At the biochemistry division, although the involvement of technician in processing the sample is low, the division accounts for about 45% of the total laboratory workload, which as a result increases the technician utilization rate.

To conclude, the results of running the baseline model with the current resource allocation policies at the selected clinics and departments indicates that the physician and nurses utilization rate is significantly low when compared to the target utilization rate of 70%-80%. Some resources, particularly emergency physicians on the afternoon and night shifts are over utilized. The under/over utilization of resources is found to be a result of inadequate staff scheduling policies for these clinics and departments. Consequently, the utilization rate of resources may be improved by changing the current scheduling policies for both doctors and nurses. Lastly, the underutilization rate of the resource at the x-ray department including ultrasound and MRI resources indicates the nature of the workload at these divisions and likely could not be improved no matter what policy changes are imposed on staff scheduling because at least one person is required. In addition, the resource assignment is currently kept low.

Table 5.6: Human resource utilization rate at the selected department and clinics.

Department	Resource	Number during shift M*	A*	N*	% Utilization during shift M	A	N
Emergency	Receptionist	1	1	1	32	45	15
	Nurse	6	4	4	25	44	28
	Triage nurse	1	1	1	43	59	20
	Physician	3	2	1	47	79	89
Family Clinic	Receptionist	2			32		
	Nurse	3			40		
	Triage Nurse	2			66		
	Physician	6			57		
Ortho clinic	Receptionist	2			19		
	Nurse	5			59		
	Technician	1			70		
	Physician	7			51		
x-ray (weekday)	Receptionist	2			22		
	x-ray Technician	6	2	1	74	46	74
	Ultrasound Nurse	1			45		
	Ultrasound Technician	1			20		
	Ultrasound Radiologist	1			44		
	MRI Radiologist	1			62		
	MRI Technician	1	1		56	60	
	MRI Nurse	1			71		
	CT Nurse	1			74		
	CT Technician	1			74		
(weekend)	x-ray Technician	2	2	1	46	47	73
Laboratory Weekday							
	Receptionist	2	1	1	64	62	50
Biochemistry	Technician	3	1	1	59	94	78
Microbiology	Technician	3	1	1	13	23	18
Hematology	Technician	3	1	1	14	26	20
Weekend							
	Receptionist	1	1	1	55	53	50
Biochemistry	Technician	1	1	1	75	82	78
Microbiology	Technician	1	1	1	17	19	18
Hematology	Technician	1	1	1	19	22	20

M* - Morning, A* - Afternoon, N*-Night

5.9.3 Capital Resource Utilization

The result of evaluating the current capital resource allocation at the clinics and departments reveals that most of the resources are underutilized. As shown in Table 5.7 resources including plaster room at orthopedic clinic, MRI machine and CT scan were found to be within acceptable utilization rates. The underutilization rate of most of the resources indicates that the hospital allocated more capital resources than it needed to deliver health care services; consequently, the utilization rate can be improved by the reallocation of these resources.

Table 5.7: Current system capital resource utilization rate and assignment.

Department	Resource	Number	Utilization (%)
Emergency	Trauma Room	3	11
	Exam Room	4	63
	Observation Room	3	20
Family Clinic			
	Exam Room	7	15
	Triage Room	2	63
Ortho Clinic			
	Exam Room	7	51
	Plaster Room	1	79
x- ray			
	Normal x-ray Machine	3	41
	Ultrasound Machine	2	32
	MRI Machine	1	75
	CT Scan Machine	1	72

Reflecting on the above, several scenarios were tested for improving the current delivery system resource utilization and average patient (LOS) at the selected departments and clinics. Table 5.8 summarizes the characteristics of each scenario.

Table 5.8: Scenarios 1-5 description.

Scenario	Description
1	Modifying staff scheduling policies and shift duration time at the emergency department.
2	Modifying staff scheduling policies and extending shifts duration time by 2 hours at the emergency department.
3	Modifying staff scheduling policies, shift duration time, and reducing non human resources at the emergency department.
4	Modifying staff scheduling policies, shift duration time, and reducing non human resources at the emergency. Modifying staff levels, and non human resources at the selected outpatient clinic. Introducing an electronic patient medical record at all departments and clinics.
5	Increasing demand level by 20% at the selected departments/clinics

The scenarios for scheduling policies and recourse allocation that were developed are detailed below.

5.9.3.1 Scenario 1

In this scenario the decision was made to modify the scheduling policies for both physicians and nurses after observing the utilization rate, both hourly and overall, and patient average (LOS) in the current system at the emergency department. In an attempt to balance the workload, improve patient average (LOS), and improve resource utilization rates the number of nurses was decreased in the morning, and night shifts by (3), and by (2) respectively as shown in Table 5.9. During system observation it was found that the peak demand at the emergency was from 4:00 p.m. to 11:00 p.m. for almost every day of the week.

Table 5.9: Staff Schedule for Scenario (1).

Resource	Shift Time	Reduction in Resources
Physician	7:00 AM - 3:00 PM	2
	3:00 PM - 12:00AM	3
	10:00 PM - 7:00 AM	1
Nurse	7:00 AM- 2:00 PM	3
	2:00 PM - 00:00 AM	4
	10:00 PM - 7:00 AM	2

Similarly, the number of emergency physicians was decreased by one physician during the morning shift, and one physician was added to the afternoon shift. Additionally, the shift duration for the morning and afternoon was modified to the one shown in the Table 5.9. The reason for this strategy of decreasing the number of nurses and physicians in the morning shift is because during observation it was found that the demand is lower at this period of time. One reason for this lower demand is that most patients tend to visit the specialist related to their health conditions in outpatient clinics that are open from 8:00a.m.-2:00 p.m. during weekdays. Another reason is the fact that decreasing the number of staff assigned to a particular task will dramatically increase the staff utilization.

The effect of running scenario (1), with the above proposed staff scheduling policy and resource allocation strategy, on patient length of stay is shown in Figure 5.10. When compared to the current delivery system, Scenario (1) had reduced the average (LOS) from 104 minutes to 69 minutes, a 30% (LOS) time reduction. On the other hand, scenario (1) had no significant impact on EMS patient (LOS) because they have the priority over the walk-in patients.

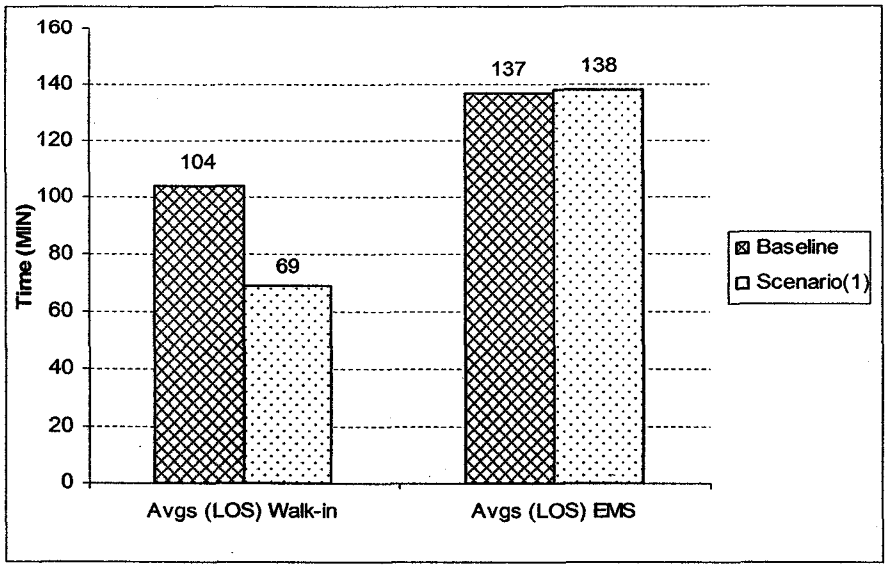


Figure 5.10: Scenario (1) average (LOS) - Emergency department.

The results of comparing resource utilization rate of scenario (1) with the current delivery system are shown in Figure 5.11. From the figure physicians during the morning shift and nurses during all shifts are all underutilized. On the other hand, the afternoon and night shift physician are over utilized. When comparing the scenario (1) resource utilization rate to that of the current delivery system, scenario (1) outperformed the current system on the physician's utilization rate by bringing it closer to the 70% to 80% target range. In addition, scenario (1) produces a substantial improvement, approximately 50%, on nurse's utilization rate during morning and night shift as shown in the figure. No impact was found of running scenario (1) on the triage nurse and receptionist utilization rate since one of each is assigned to each shift. Likewise, there was no impact noticed on the other clinics and departments as a result of scenario (1).

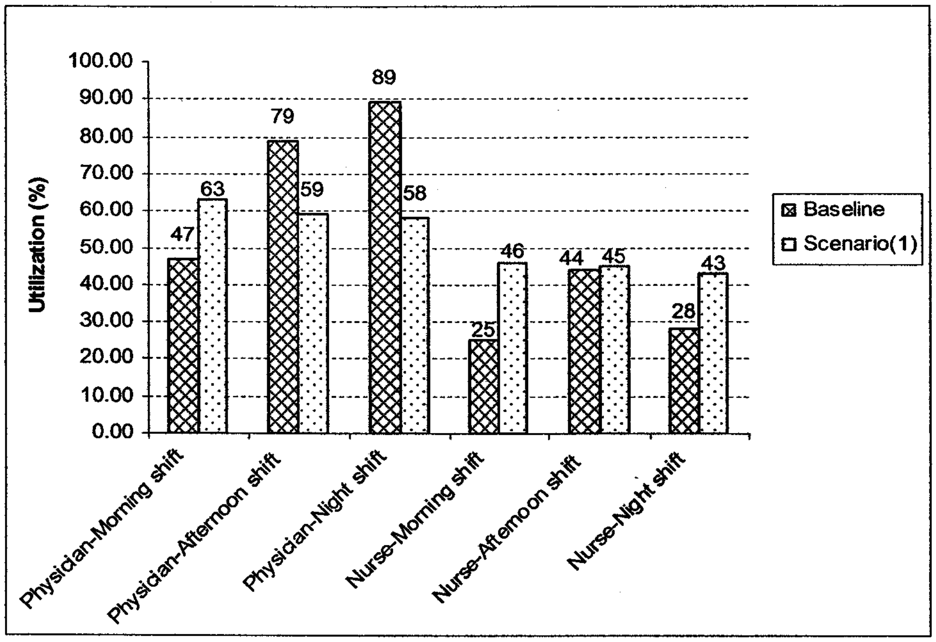


Figure 5.11: Comparison of current system and scenario (1) resource utilization.

5.9.3.2 Scenario 2

Scenario (2) was run under the emergency department staff scheduling policy shown in Table 5.10. The working hours of physicians and nurses during morning shift was extended by 2 hours.

Table 5.10: Emergency staff scheduling -Scenario (2).

Resource	Shift Time	Reduction in Resources
Physician	7:00 AM - 4:00 PM	2
	4:00 PM - 1:00 AM	2
	10:00 PM - 7:00 AM	1
Nurse	7:00 AM- 4:00 PM	3
	4:00 PM - 1:00 AM	3
	10:00 PM - 7:00 AM	1

The number of physicians on the morning shift was decreased by 1 and the number of nurses was decreased by 3, and by 1 in the morning and afternoon shift respectively. The impact of the change in the staff scheduling policy on emergency patient (LOS) is shown in Figure 5.12.

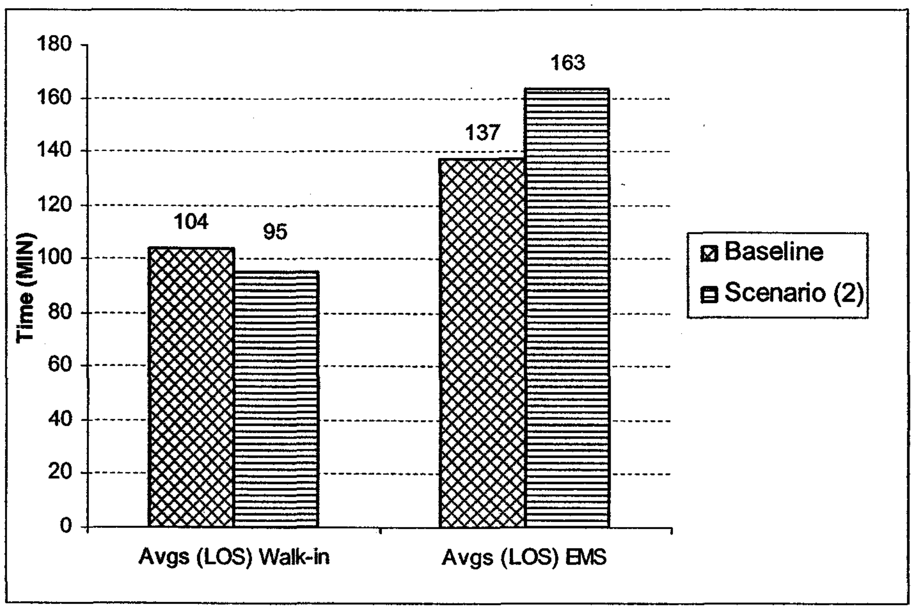


Figure 5.12: Scenario (2) average (LOS) - Emergency department.

From the figure, the impact of staff scheduling policy of scenario (2) is insubstantial on walk-in patient average (LOS) since it produced only 9% reduction of time. Moreover, the policy has increased the average EMS (LOS) by almost 19%.

On the other hand, the improvement this policy produced in resource utilization is significant as shown in Figure 5.13. This policy enhanced the physician utilization rate during night and morning shifts by bringing it to 67 %, which is closer to the target utilization rate of 70% - 80%. On nursing staff, a substantial improvement on utilization rate was noticed. The policy improved the utilization rate, particularly during morning, afternoon and, night shift, as scenario (2) produced 49% and 62% and 61% respectively.

This scenario has no impact neither on resource utilization nor on patient waiting time on the other clinics and departments.

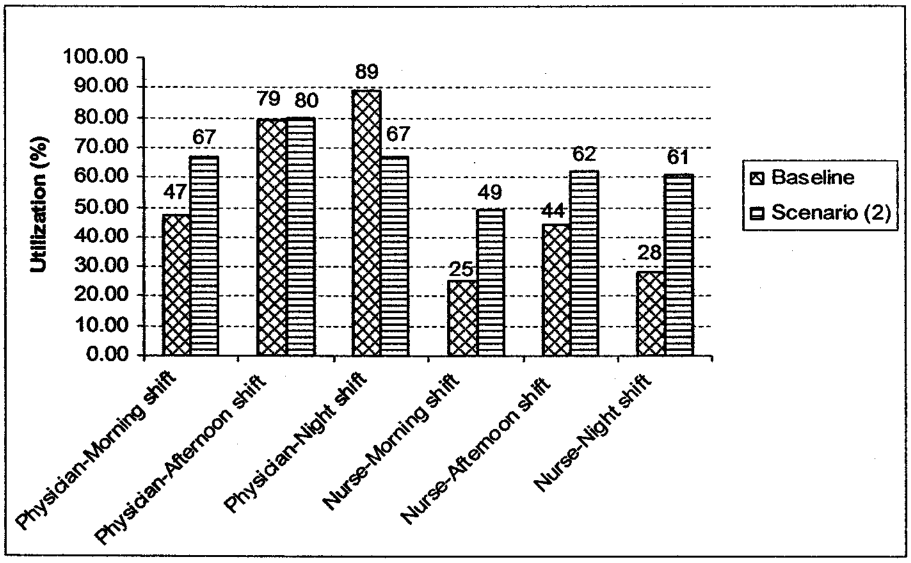


Figure 5.13: Scenario (2) resource utilization – Emergency Department.

5.9.3.3 Scenario 3

In scenario (3) it was decided to run the current delivery system with the same staff scheduling policy used for scenario (1) but reducing the examination rooms, observation rooms, and trauma rooms to 3, 2,and 2 respectively. The objective was to streamline the non-human resources utilization rate and evaluate the impact of such decision on patient length of stay at the department. Results of the impact of scenario (3) on patient average (LOS) for both walk-in and EMS patient and are shown in Figure 5.14. Compared to the current system, this alternative reduced the average (LOS) of walk-in patients by 25 minutes but had no significant impact on EMS patient average (LOS). On the other hand, when compared with scenario (1), scenario (3) increased by 5 minutes waiting time. The extra time encountered in scenario (3) is a result of patient waiting until the doctor and the exam/treatment room are available.

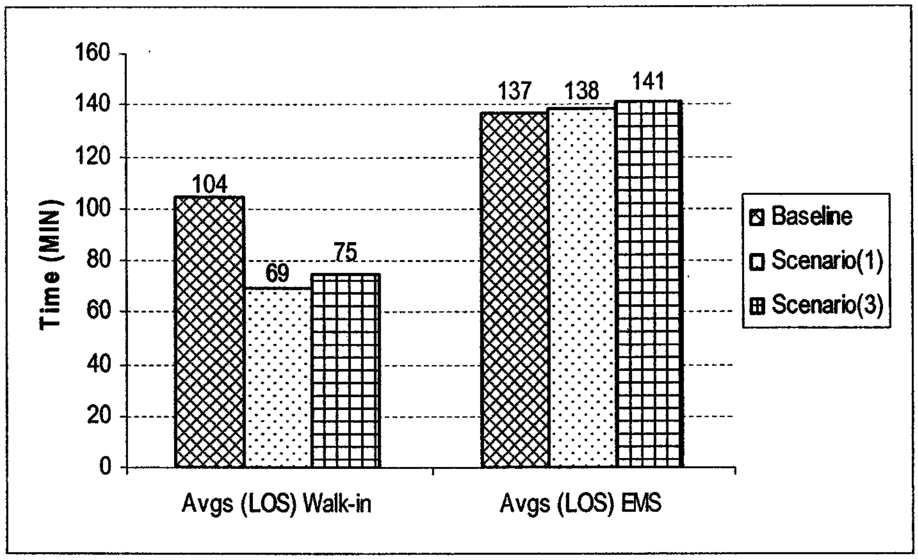


Figure 5.14: Baseline, Scenario (1), and (3) average (LOS) – Emergency Department.

When evaluating the impact of running scenario (3) on resource utilization, a substantial resource utilization improvement can be noticed as shown in Figure 5.15. The over utilized baseline scenario night shift physician with 89% utilization rate now drops to a 62 % utilization rate in scenario (3).

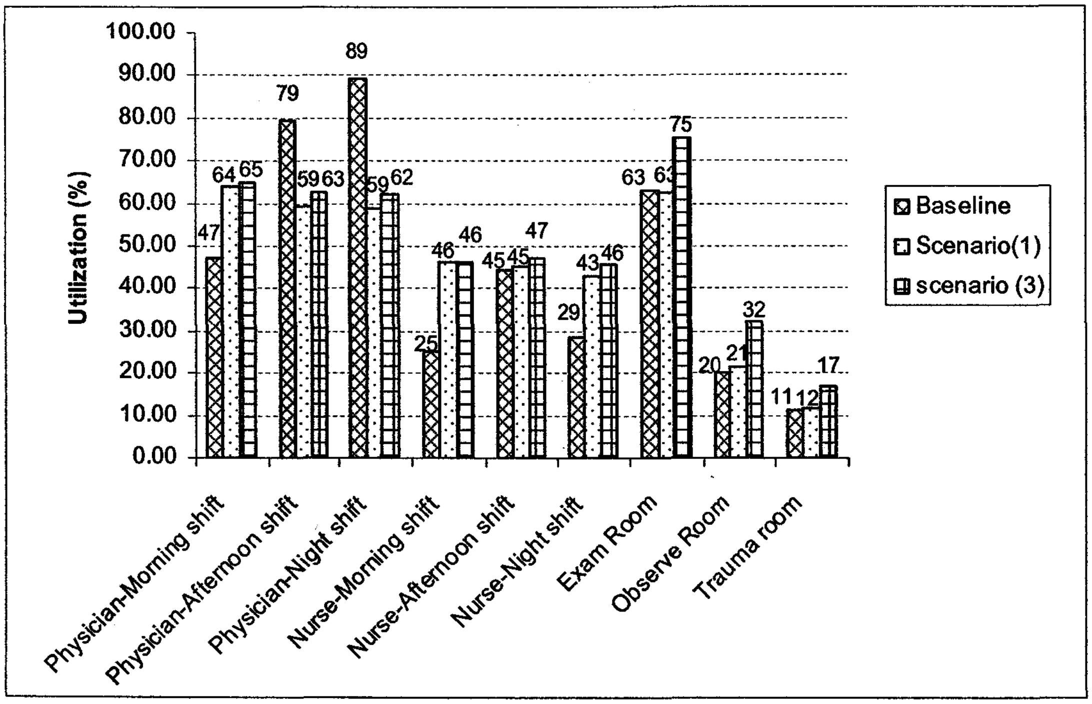


Figure (5.15): Scenario (3) resource utilization rate

Also noticed is a balanced workload for physicians in all shifts as the scenario produced a utilization rate of 65 %, 63 %, and 62%. The case is similar for nursing staff with 47%, 46%, and 46% utilization rate. When comparing scenario (3) with scenario (1) no major difference is found in the utilization rate for physicians or for nurses. This was expected since both scenarios are executed with the same staff scheduling policy. Another improvement resulting from Scenario (3) is the room's utilization rate by producing 75 %, 32 %, and 17 % utilization rate for, exam room, observation room, and trauma room respectively. The baseline scenario has current rates of 63%, 20%, and 11% respectively.

5.9.3.4 Scenario 4

Scenario (4) intends to enhance the delivery system at the x-ray, emergency, and family and orthopedic clinics. Experimentation in this scenario puts more emphasis in the available staff schedules as measured by the number of nurses, technicians, and physicians on duty for each hour of the simulation run. The resource assignment policy shown in Table 5.11 was input in to the model with an initial effort to enhance the resource utilization rate and decrease the average (LOS) at the two clinics. The proposed staff's scheduling policies differ only on the number of physicians, nurses, receptionist,

Table 5.11: Scenario (4) resource assignment for orthopedic and family clinic.

Ortho Clinic			Family Clinic		
Resource	Current	Scenario (4)	**Resource**	Current	Scenario (4)
Physician	7	5	Physician	6	5
Nurse	5	4	Nurse	4	3
Exam Room	7	5	Triage nurse	2	2
Receptionist	2	1	Exam room	7	5
			Receptionist	2	1

and available rooms from the current delivery system. The actual operating hours are kept the same as the current system. At the emergency department it was decided to use the staff scheduling policy and resource assignment used in scenario (3) as it outperformed scenario (1) and (2) in resource utilization rate and decreased patient average (LOS) when compared to the current system. Additionally, this scenario accounted for the effect of introducing an electronic patient medical record to reduce administrative inefficiency, to improve access to patient information and to improve access to health care service by reducing patient time. The problem of walk-in patients having to wait for their medical records to be brought to the clinic existed in the orthopedic and family clinics as explained earlier. During the observation and process evaluation phase it was found that these patients account for 30%-35 % of the total daily patients at both clinics. Likewise, the x-ray department experienced the same problem. The receptionists are never aware of which patient will be arriving for imaging on a particular day. This prevents them from pulling the folder prior to the patient's arrival. According to the current process, the patient arrives in radiology with an exam requisition. The receptionist must leave the reception area to retrieve the patient folder. Pulling priors records at the same time of patient arrival increases the patient wait time. Misfiled or missing folders can also cause delays, impacting patient waiting time. Additionally, there is only one file number for all family members. To find a film for an individual patient, all films in the folder must be separated to ensure that the pertinent priors are retrieved, a process that normally leads to time delays. Therefore, this scenario intended to evaluate the effect of introducing and an electronic medical record (EMR) system at the two clinics, and the emergency, and x-ray department. The effect of running the current delivery system with the above staff scheduling policy and resource assignment on patient average (LOS) is shown in Figure 5.16. As presented in the figure, scenario (4) produced an average (LOS) at all clinics but the EMS patient at the emergency department. Of interest, the walk-in patient average (LOS) at the emergency was reduced from 104 to 72 minutes and the average (LOS) for x-ray procedure was reduced from 38 to 25 minutes. Although the reduction in average (LOS) at the family and orthopedic clinics scenario (4) provided might not be significant in terms of time saving it is less than that of the current system. Additionally, it required less human and non-human resources as indicated earlier, which means labor cost savings.

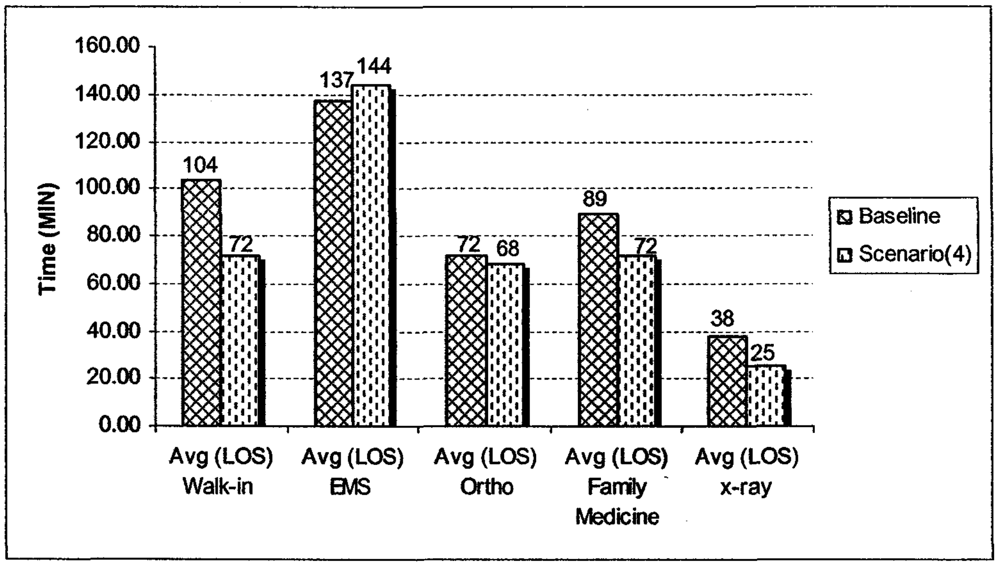


Figure 5.16: Scenario (4) Average (LOS) for the selected clinics and department

Moreover, implementing an electronic medical record system (EMR) at the clinics and the x-ray department is a key factor in managing operations effectively. An (EMR) would not only reduce costs in time but it will also improve access to patient information, and eliminate lost patient information.

In terms of resource utilization, scenario (4) significantly outperformed the current delivery system as shown in Figure 5.17.

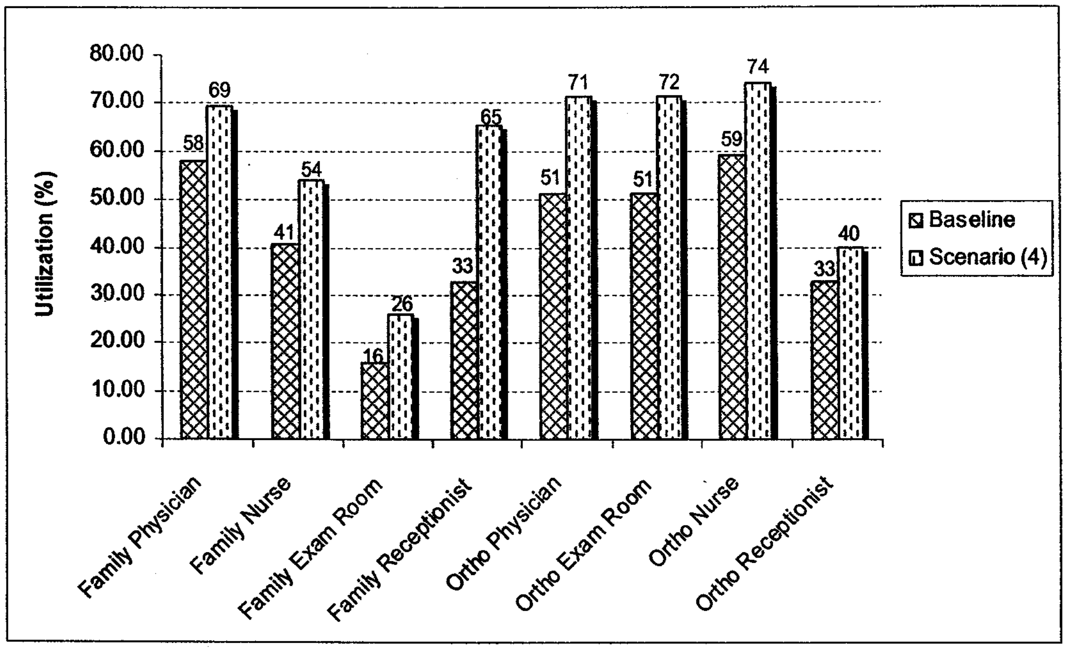


Figure 5.17: Scenario (4) resource utilization rate.

The physician utilization rate at both family and orthopedic clinics had been increased to 70 %, which was one of the objectives of this alternative. This was achieved by reducing the number of physicians, which definitely means reducing the clinic operation costs. The case was similar for the nurses' utilization rate since output from scenario (4) gave a rate that is close to the target range of 70%-80% after reducing the number of nurses in both clinics. Additionally, a utilization rate improvement was also achieved on receptionist and exam rooms at both clinics as shown in the Figure 5.17. The impact of this scenario on the emergency operation, average (LOS), and resource utilization when compared to scenario (3), was found insignificant since no changes have been noticed on emergency output after adopting the conditions proposed in this scenario. This was expected since the same resource assignment and staff-scheduling policies were used for both scenarios.

5.9.3.5 Scenario 5

This scenario attempts to answer the question of how would the health care delivery system at the selected clinics and departments perform if the demand for services increased while the baseline resource management assignment and staff scheduling is maintained. In addition, this alternative is used to analyze the impact of increased demand on patient (LOS) and resource utilization. It order to answer the above question and to understand the behavior of the current delivery system under the new condition of increasing demand, it was necessary to determine what is the level of increase in demand. Since there were no records kept concerning the level of increase in demand at the selected clinics and departments it was decided for the purpose of this experiment to assume a 20% increase in the level of demand. The 20% increase in demand incorporated represents walk-in patients, since the number of appointments that can be given is controlled by the clinic administration. The attempt here is not to determine the resources required to achieve the 20% increase in demand, but rather as indicated earlier to evaluate the behavior of the system under such operating conditions. Table 5.12 shows the percentage of demand level increase and the number of patients associated with that increase.

Table 5.12: Increases in demand levels.

Clinic/ Department		Demand As-Is	20 % increase per day
Emergency	- Walk-in	147	176
	- EMS	4	5
Ortho clinic		22	26
Family clinic		40	48
Laboratory		418	502
X-ray		48	58

The results of the impact on average (LOS) obtained after running this scenario are presented in Figure 5.18.

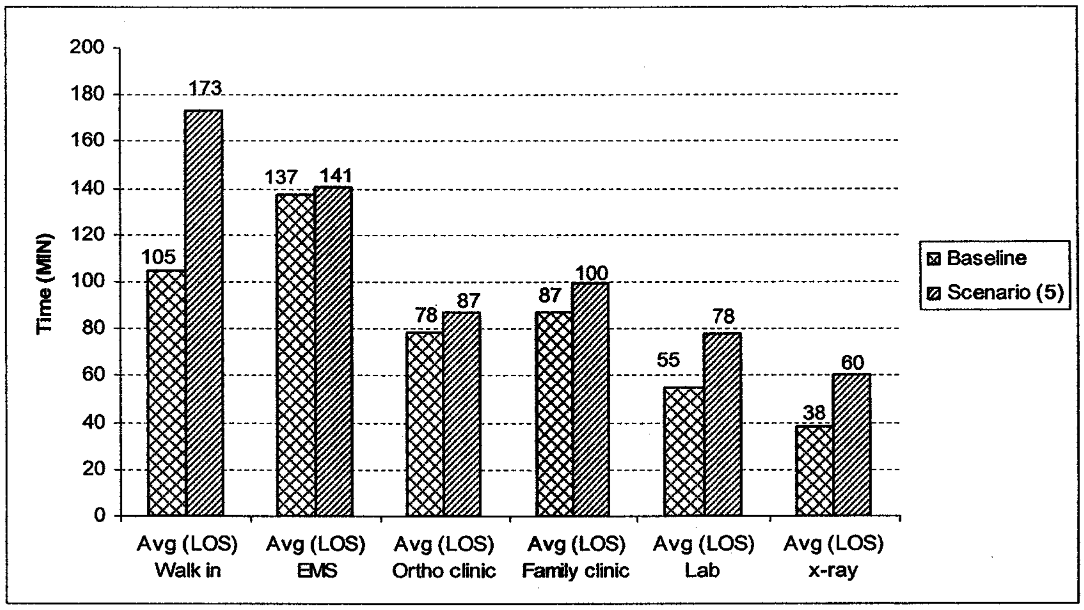


Figure 5.18: Scenario (5) average (LOS) at the selected departments/clinics.

When analyzing the results shown in Figure 5.18 a significant increase on the patient average (LOS) at the emergency, x-ray and lab can be noticed. The 20 % level of increase in demand produced an average (LOS) of 173 minutes at the emergency department compared to104 minutes under the current system. Part of this increase on the average (LOS) at the emergency department is a result of the increase on the average (LOS) of both departments as this alternative produced 60 and 78 minutes at x-ray and laboratory respectively. That impact of increasing the demand level on the family medicine and orthopedic clinic average (LOS) was insubstantial when compared to that of the current system as it generated 100 and 87 minutes average (LOS) respectively. The reason for this is that the walk-in patients represent a small portion of the total daily demand at both clinics. The effect on resource utilization at the emergency department after incorporating the increased in demand into the model is shown in Figure 5.19.

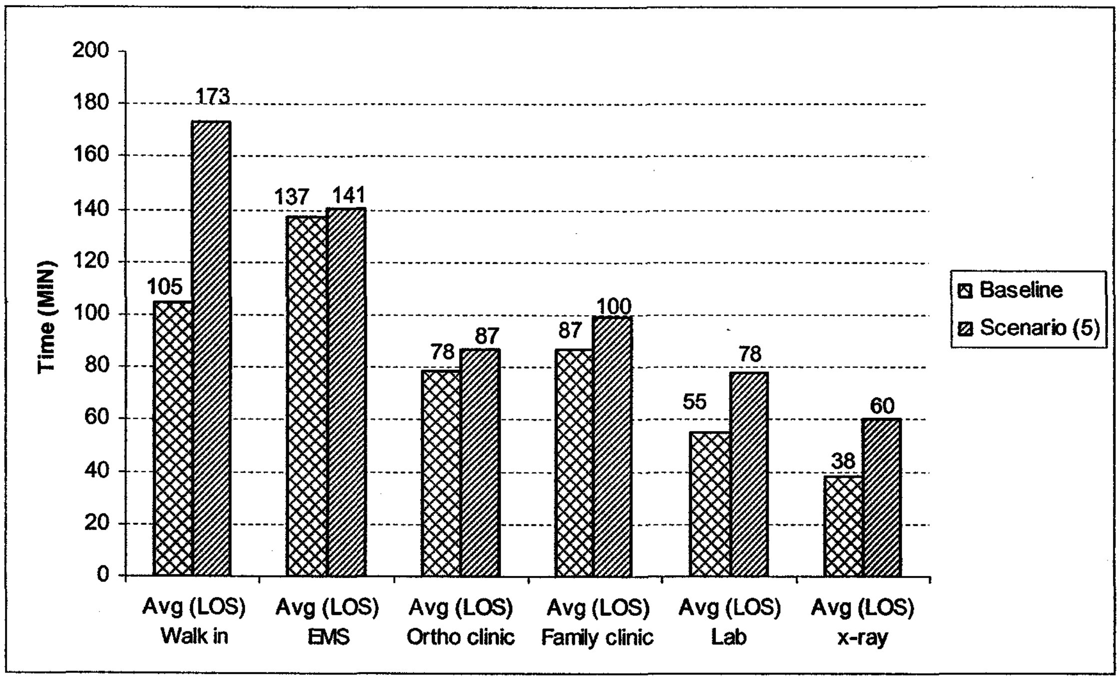


Figure 5.19: Scenario (5) resource utilization at Emergency department

The main effect of the new change is easily noticed on the physician for the afternoon and night shifts as it produced 84 % and 99% utilization rates respectively. This indicates that for the department to cope with this new increase for these two shifts, it is necessary to use a different resource assignment policy if the system performance is not to be altered. On the other hand, the impact of this increase on other emergency resources has no main effect as shown in the figure.

At the two outpatient clinics, family and orthopedic, the increase in demand level did not affect system performance since it has a minimum impact on resource utilization as seen in Figure 5.20. Although the increase generated a utilization rate of physician and nurses that is higher than the current system yet, it is still not close enough to target rate of 70%-80% utilization rate.

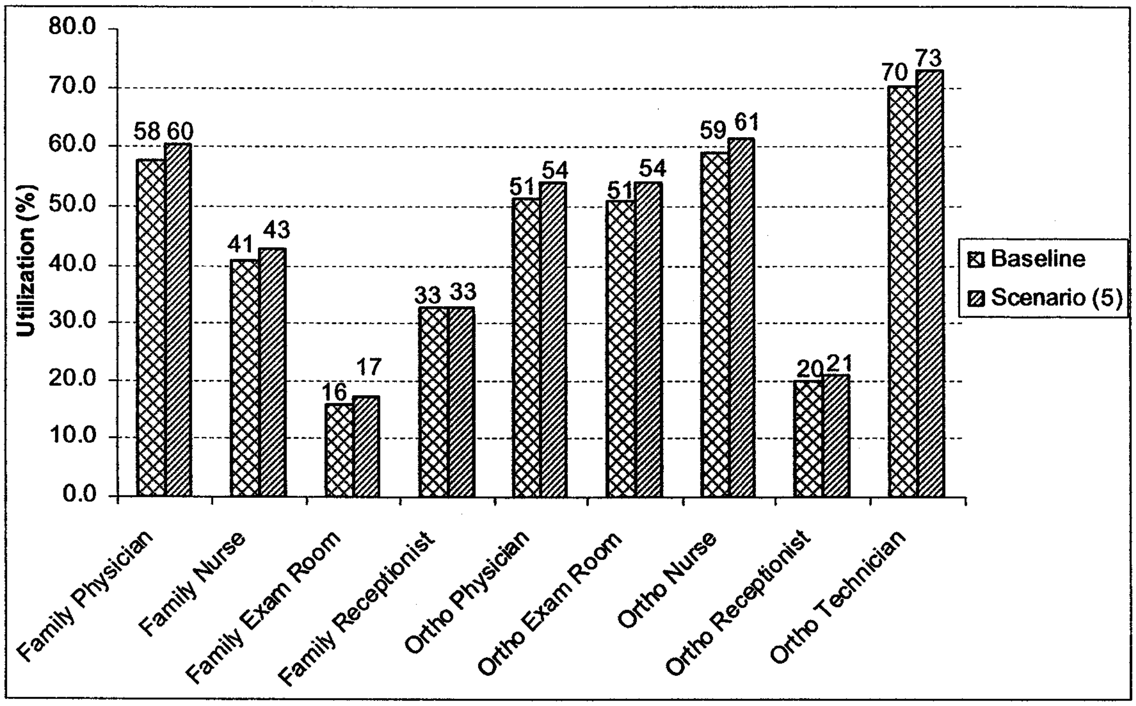


Figure 5.20: Scenario (5) resource utilization at family and orthopedic clinics

In the case of capital resources the increase on demand level could be satisfied even with less resources as the increase produced no significant impact on the utilization rate of these resources.

For the radiology department, the simulation model for the current system, using the new demand level for the same resource configuration, indicted that performance when measured by resource utilization rate would not be affected. Resources at CT scan, MRI, and ultrasound were not affected by this increase since the services at these divisions were prescheduled. All other resources as shown in Figure 5.21 are underutilized except the x-ray technicians on the morning and night shift during weekdays and night shift technicians on weekends. To conclude, the increase in demand shows no significant effect on x-ray department operations.

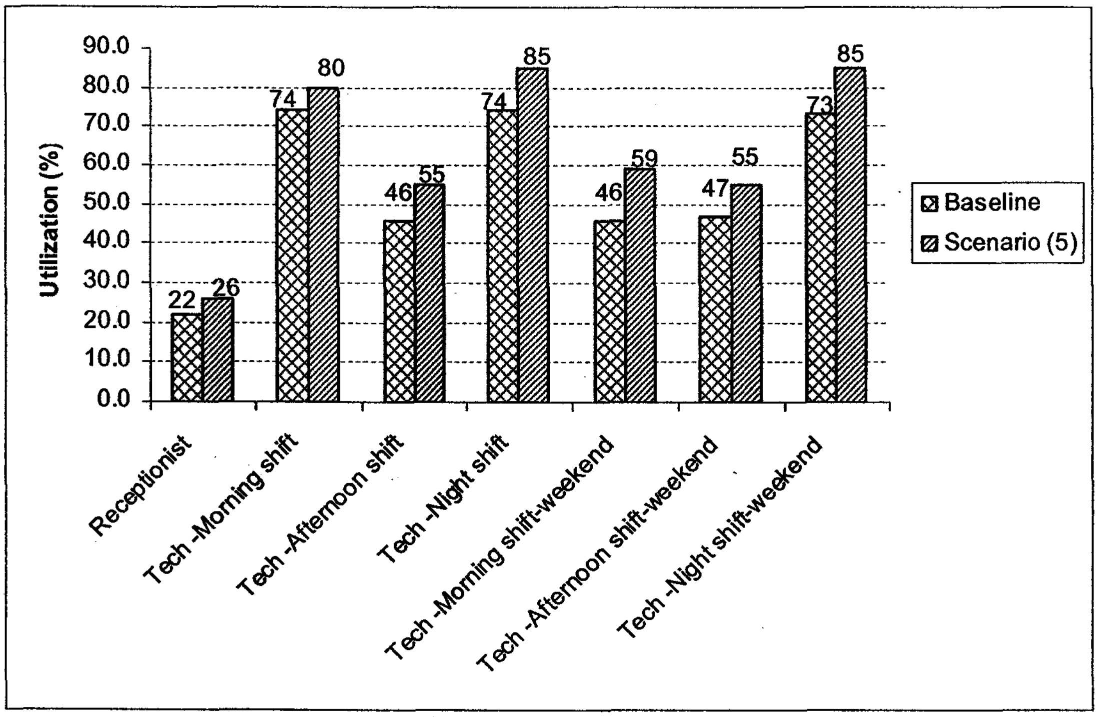


Figure 5.21: Scenario (5) resource utilization at X-ray Department.

The results obtained after running the model for the laboratory are given in Figure 5.22. The figure represents only the effect on the utilization rate of resources at the biochemistry division, since it is the only effect this alternative produced.

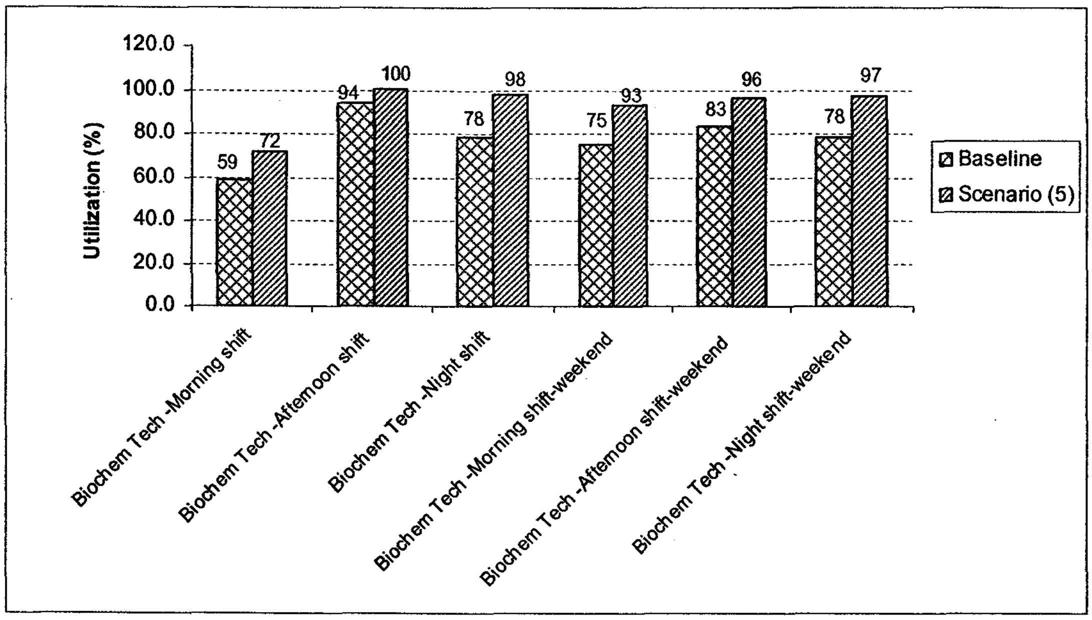


Figure 5.22: Scenario (5) X-ray resource utilization

This was expected as indicated earlier since this division accounts for most of the laboratory workload. In the case of the hematology and microbiology divisions no significant impact was noticed. According to the figure, the increase on demand level can not be satisfied with the current technician resource assignment and scheduling policies as it produced more than 90% technician utilization rate.

5.9 Summary of Results

In this chapter the basic objective of this chapter was to develop and validate a model that best describes the real delivery health care system at the selected departments and clinics at Zayed Hospital. This was an attempt to investigate problems and concerns from management, staff, and end-users related to waiting time, inadequate resource planning and allocation practices in the current delivery system. To accomplish this objective the first step was to prepare data for model input. In this step, reliable, relevant and accurate data, that best represented the operational aspects of the current delivery system was prepared and used as input for the med model software. At each clinic and department selected, the model logic was basically a representation of a queue system where patients (entities) enter the system, receive medical service and then leave the system. The patient flow within the system from server to server is based on the treatment regime prescribed for patients based on their condition or illness. The second step was to verify and validate the developed model. Three approaches were used to conduct this step. These were: (1) data validity, (2) computerized model verification, and (3) operational and output validation. As result the developed model was found to be a valid representation of the real delivery system at the selected departments and clinics.

The third step was experimentation with the model. In this step the simulation model was executed to test the following major factors that influence the performance measures and concerns voiced by end-user, staff, and management about at the selected departments and clinics:

(1) Number of patients at each clinic;

(2)Staffing levels at each clinic;

(3) Number of servers at each clinic;

(4) Staff scheduling policies and timetables.

The above factors were used to examine the following performance measures:

(1) Total patient length of stay (LOS) from registration completion to discharge;

(2) Patient average waiting time for a resource;

(3) Patient average time in operation (processing time);

(4) Resource utilization rate at each clinic and department; and

(5) Number of patients in queue at each process.

The following general conclusions can be drawn about the model developed for the selected clinics and departments[156]:

1. The current health care system at the selected departments and clinics presented a scope for improvements in patient throughput, access to services, and resource utilization.
2. The simulation model accurately represents the real life operations at the selected departments and clinics. Output from the model has proven to be a representation of the real life operations of the clinics/departments for which the system was observed and data collected.
3. Using the proposed improvement approach, methodology, and simulation, optimal solutions for efficient planning and allocation of resources can be achieved.

For experimentation purposes, different staff-scheduling policies and resource assignment were proposed and evaluated with the simulation model. The arrival patterns at the selected departments and clinics significantly affected the waiting time and resource utilization rate. Similarly, different staff levels also affected the performance measure at each clinic and department. It was found that at a point of time when the average patient load is high some resources were over-utilized, and in the case where the average load was small, the resources were unaffected. In the case where resources are underutilized, it was found that the hospital allocated more resources than it needed to deliver services. This was a result of the current inadequate planning and resource management practices. Reallocating these underutilized resources to value added activities that best represent patient, and staff needs and requirements is the solution to resolve the underutilization problem. Increased staff levels in some shifts during the day resulted in decreased patient average (LOS) and brought the staff utilization rate closer to the targeted utilization rate 70%-80%.

Introducing an electronic patient medical record (EMR) allows healthcare providers at Zayed hospital to save time and money, enabling them to better care for their patients. The EMR streamlines the diagnosis and treatment processes. It allows physicians to efficiently and cost-effectively manage their patients' full clinical experience, including appointment scheduling, office visits, labs, health maintenance, referrals, authorization and medications. Moreover, the EMR enables physicians and their staff to focus on their patients instead of paperwork, enhances patient care, improves efficiency, increases profitability and helps medical practices stay current and compliant with industry standards and regulations

Normally, the impact of increasing service demand levels at hospital results in increase patient average (LOS), patient delays, and resource utilization rate. This was not the case in some of the selected clinics and departments since these clinics allocated more than the needed resources. Since no records were kept for demand growth at the hospital, a 20% demand increase was assumed to evaluate the impact of demand increase. This experiment was designed and conducted to test the behavior of the current system when increasing the demand for service. If the hospital is to plan and allocate resources efficiently it must be able to predict the actual demand growth in services. Moreover, the predicted growth should be evaluated for long-term trends and correlations between these trends and the characteristics of the calling population at the hospital. In additions, for the hospital to efficiently plan and allocate resources accordingly it is very important to study the behavior of system variables under different demand levels and to evaluate how much the system is able to afford without altering the system performance of an acceptable service level.

Chapter 6

Conclusions and Recommendations

This chapter sets out to present the conclusions and recommendations for this research study. The first section contains the conclusions drawn from conducting this research. The second section includes suggested future recommendations for further studies in the area of resource management.

6.1 Conclusions

As indicated earlier in this thesis, the development of the improvement framework is an effort to aid the strategic and operational decision-making in resource management for service organizations. With a focus on statistical data and input from problem owners, the general framework proposed in the study has proven to be useful in analyzing an existing service delivery system at Zayed Hospital.

The previously well described new improvement framework and the methodology presented in this study governed the modeling process for selected departments and clinics at the hospital. Patient and staff satisfaction surveys helped identify the key decision variables of the model and offered an insight into what data to collect when defining the operational aspects of the current health delivery system at the selected departments and clinics. Moreover, reliable and relevant data that best describe system operations and represent workforce concerns and problems were achieved by using a continuous data improvement process (PDSA cycle). The (PDSA) cycle facilitated the model verification and validation processes and helped in identifying activities that have a major impact on system performance. The management, staff, and patient involvements were essential in determining the real system problems and as a result, model objectives, accurate current system details, and areas for improvements were easily determined. At the early stages and throughout the process of developing the simulation model, Zayed Hospital management and staff gained greater detailed knowledge of their operations and procedures at the selected clinics and departments.

The methodology used in this research helped to observe and predict consequences of change in resource management policies prior to decisions actually being implemented and without the disruption and expense associated with trial and error. The use of the methodology and tools proposed in this research proved to be very beneficial to Zayed hospital in attempting to determine the efficient resource allocation and planning practices. To observe the consequences of changes in the current resource management policies at the selected departments/clinics five scenarios were developed and analyzed. Based on the analysis performed along with the results of comparing different scenarios to the current system, it can be concluded that effective and efficient decision-making on resource allocation and planning can be achieved. Adoption of one of the developed scenarios can improve resource utilization and enhance patient throughput and access to care. Consequently, reducing patient length of stay is one way by which more patients can be seen at the selected departments/clinics.

To conclude, the main characteristics that define the novelty of the proposed improvement framework are the followings:

- The first to account for the involvement of stakeholders (management - staff - end user – analyst).
- The first to provide a continues data improvement mechanism throughout the modeling efforts (PDSA) cycle.
- The first to provide an effective and efficient measure for post evaluation.
- Focuses on the most significant system variables that best represent stakeholders' needs and requirements.
- Engineering Methodology and management techniques are shown to be effectively utilized for evaluating a health care delivery system.

6.2 Recommendations for future work

To conclude this research, there are many directions for further studies in the area of resource management that can be considered for future work. These are listed below.

1. The operational aspects of other clinics and departments at Zayed Hospital may be investigated using the proposed improvement framework and methodology described in this research and based on the experienced gained in the case study.
2. To additionally test the applicability of the proposed improvement approach to other service delivery systems in different industries, the approach and

methodology can be applied to other service delivery systems with some modifications related to the area of application.

3. The growth in service demand at Zayed Hospital should be examined for long-term trends if the hospital is to plan and allocate resources efficiently.
4. A large-scale study should be conducted to evaluate the laboratory department at Zayed Hospital. This could include defining all operational aspects of the laboratory process, amount of available equipment, capacity of equipment, number of tests at each division, and turnaround time for each test.
5. In addition to the decision variables used in this study, the service delivery system could be investigated using cost (salaries and wages) as a decision variable. This could be expanded to include costs for equipment and tools necessary to deliver services.
6. To test the efficiency and effectiveness of the alternative solutions proposed in this study in achieving the objectives and solving problems, patient and employee satisfaction surveys should be conducted for the same period of time after implementing the new resource management polices.

References

[1] Katz J., Aldrich H., Welbourne M., and Williams M., "Guest editors comments special issue on human resources management and the SME: Towards a new synthesis. Entrepreneurship theory and practice, 2000.

[2] The conference board of Canada, "The future cost of health care in Canada, 2000 to 2020", 2001 Report.

[3] Bulatao A., Bos E., Stephans w., and Vu T., "World population projection 1989-90 edition: short-and long term estimates", World Bank Report No.9190 (the Johns Hopkins University press), 1990.

[4] Statistics Canada, "profile of the Canadian population by age and sex: Canada ages", 2001.

[5] Greengross S., Murphy E., Quam L., Rochon P., and Smith R., "Aging: a subject that must be at the top of the world agendas, British Medical Journal , Vol.315, 1997, pp1029-1030.

[6] Luke D., and Begun W., "Strategy making in health care organizations", In: Shortell SM, Kaluzny AD, editors. Health Care Management: Organization Design and Behavior. Albany, NY: Delmar, 2000, pp 394-431.

[7] Thomas C., "The future of the organization; Achieving excellence through business transformation", Kogan Page Limited. London, 1997.

[8] Ozcan A., and Smith P., "Towards science of the management of health care", health care management science, Vol.1, 1998, pp1-4.

[9] Skinner J., "The non-sustainability of health care financing under the Medicare model", AIMS health care reform, 2002.

[10] Walker M., and Esmail N., "Waiting your turn: Hospital waiting lists in Canada-2002".Fraser Institute, 2002.

[11] Jonsen R., Siegler M., and W. J. Winslade J., "Clinical Ethics: A Practical Approach to Ethical Decisions in Clinical Medicine", 4th edition ,McGraw-Hill, New York, 1998.

[12] Bowen E., Gilliland W., and Folger R., "HRM and Service Fairness: How Being Fair with Employees Spills Over to Customers", Organizational Dynamics, Vol.27, No.3, 1999, pp7-23.

[13] Brody H., and VandeKieft G., "Managed Care', in J. Sugarman (ed.), 20 Common Problems– Ethics in Primary Care (McGraw-Hill, New York), 2000, pp81–92.

[14] Geoff R., "Shifting the balance of health care into the 21st century", European Journal of Operational Research, Vol. 105,1998, pp267-276.

[15] Sanchez M., Ferrin D., Ogazon T., and. Sepuveda A., "Emerging issues in health care simulation", Proceeding of the 2000 winter simulation conference, Institution of Electrical and Electronics Engineers, Orlando, Florida, USA, 10 – 13 Dec, 2000, pp 1999-2003.

[16] Hill P., Grady O., Miller B., Boswell K., "The patient care development program: organizational development through user and staff involvement", International Journal of Health Care Quality Assurance, Vol. 13/4, 2000, pp153-161.

[17] Eldabi T., Irani Z., and Paul J., "A proposed approach for modeling health care systems for understanding, Journal of Management in Medicine Vol.16.2/3, 2002, pp 170-187.

[18] Stevenson K., Sinfield P, Ion V., and Merry M., "Involving patient to improve service quality in primary care", International Journal of Health Care Quality Assurance, Vol.17.5, 2004, pp 257-282.

[19] Wilson T., "Implementation of computer simulation projects in health care" Journal of Operational Research Society, Vol.3, 1981, pp825-832.

[20] Maleck M., Rasquinha J., and Vacani P., "Strategic issues in health care management", Hohn Wily& sons Ltd, 1993.

[21] Lapierre D., Batson C., and McCaskey S, "Improving on-time performance in health care in health care organizations: a case study", Health Care Management Science, Vol. 2, 1999, pp 27-34.

[22] Robbins L., "An Essay on the Nature and Significance of Economic Science", 3rd Ed, London: The Macmillan Press, Ltd., 1984.

[23] Dorfman R., (1976), "Prices and Markets", third edition, Prentice-Hall, INC, Englewood Cliffs, New Jersey, 1976.

[24] Roth A., "World class health care", Quality Management in Health Care, Vol.3, No.1,1993, pp1-9.

[25] Dirne W., (1990), "Production control for flexible automated manufacturing stations in low volume component manufacturing", PhD thesis, Eindhoven University of technology, 1990.

[26] Legnick C., "Customer Contributions to Quality: a different view of the customer-oriented firm", Academy of Management Review, Vol.21, No.3, 1996, p791.

[27] Harris E., Luft C., Rudy W., and Teirney M., "Correlates of Health Care satisfaction in inner-city patients with hypertension and chronic renal insufficiency", Social Science in Medicine, vol 41, No.12, 1995, pp1639-1645.

[28] Drug Topics, "Study Finds Diabetics often Non Compliant, Dissatisfied",1998

[29] Salimbene S. "Cultural Competence: A Priority for Performance Improvement Action", Journal of Nursing Care Quality, Vol.13, No.3, 1996, pp23-35.

[30] Moore A., and Schlegelmilch B., "Improving Service Quality in an Industrial Setting" Industrial Marketing Management, Vol. 23, No.1, 1994, pp 83-92.

[31] Berry L., Parasuraman A., and Zeithaml A., "The Service Quality Puzzle.", Business Horizons, Vol.31, No.5, 1988, pp53-43.

[32] Vikas M., and Baldasare M., "Eliminate the negative: managers should optimize, rather than maximize performance to enhance patient satisfaction", Journal of Health Care Marketing, Vol.16, No.3, 1996.

[33] Baliga Z., and Robert Kampf R., "Managing Perceptions of Hospital Quality: Negative Emotional Evaluations can undermine even the best clinical quality", Marketing Health Services, Vol.17, No.1, 1997, p28.

[34] Sherden, W.A "Gaining the Service Quality Advantage" Journal of Business Strategy 9, no2 1988.

[35] Shetty K., "Product Quality and Competitive Strategy" Business Horizons, Vol.30, No.5, 1987, pp 46-52.

[36] Taylor A.," Distinguishing Service Quality from Patient Satisfaction in Developing Health Care Marketing Strategies." Hospital and Health Service Administration, Vol.39, 1994, pp221-236.

[37] Couch B., "Health care quality management for the 21st century", Hillsboro Printing Company, Tampa, Florida, 1990.

[38] Zeithmal A., Parasuraman A., and Berry L., "Delivering quality service: balancing customer perception and expectations", New York: The Free Press,1990.

[39] Minjoon J., Peterson R., and Zsidisin A, "The Identification and Measurement of Quality Dimensions in Health Care: focus group interview result", Health Care Management Review, Vol.23, No.4, 1998, p81.

[40] O"Brien J., and Edward H., "The Physician's role in Quality Assessment and Improvement", Topics in Health Care Financing, Vol.18, No.2, 1991, pp33-45.

[41] Donabedian A., "Explorations in Quality Assessment and Monitoring". The Definition of Quality and Approaches to its Assessment. Ann Arbor MI Health Administration Press, Vol.1, 1980.

[42] Lagergren M., "What is the role and contribution of models to management and research in the health services? A view from Europe", European Journal of Operational Research, Vol.105, 1998, pp257-266.

[43] Kochikar V., and Narendran T., "On using abstract models for analysis of flexible manufacturing systems", International Journal of Production Research, Vol.32, No.10, 1994, pp2303-2322.

[44] Karnon J., and Brown J., "Selecting a decision model for economic evaluation: a case study and review", Health Care Management Science, Vol.1, 1998, pp133–140.

[45] Lieu T., Watson S., and Washington A., "The cost-effectiveness of prenatal carrier screening for cystic fibrosis", Obstetrics and Gynecology, Vol.84, No.6, 1994, pp903-912.

[46] Fletcher j., Hicks N., Kay J., and P.A. Boyd P.," Using decision analysis to compare policies for antenatal screening for Down's syndrome", British Medical Journal, Vol.311, 1995, pp351-357.

[47] Dittus R., and Klein R., "simulating medical decision trees with random variables parameters", In : Swain J., Goldsman D., Crain R. and Wilson J. (eds) ,Proceeding of the 1992 winter simulation conference, Institution of Electrical and Electronics Engineers, Arlington, Virginia, USA, 13-16 Dec, 1992, pp 65-73.

[48] Revicki D., Brown R., Palmer W., Bakish D., Rosser W., Anton S., "Modeling the cost effectiveness of antidepressant treatment in primary care", Pharmacoeconomics,Vol.8, no.6, 1995, pp524-540.

[49] Briggs A., Sculpher M., Logan R., Aldous J., Ramsay M., and Baron J., "Cost effectiveness of screening for and eradication of Helicobacter pylori in management of dyspeptic patients under 45 years of age", British Medical Journal, Vol.312, No.7042, 1996, pp 1321–1325.

[50] Sonnenberg F., and Deck J., "Markov models in medical decision making: a practical guide", Medical Decision Making, Vol.13, 1993, pp322-338.

[51] Birkmeyer JD, Marrin CA, OConnor G-T, "should patients with Bjork-shiley valves undergo prophylactic replacement?", Lancet,Vol.340, 1992, pp520-523.

[52] Banks J., Carson S., Nelson L., and Nicol M., "Discrete Event System Simulation", 3rd ed., Prentice-Hall, Upper Saddle River, NJ, 2000.

[53] Banks J., Spearman M., and Norman V., "Second look at simulation", OR/MS Today, Vol.22, No.4, August 1996.

[54] Pegden R., Sadowski P., "Introduction to Simulation using SIMAN", Second Edition. McGraw-Hill, 1995.

[55] Pidd M., "Computer Simulation in Management Science", Wiley, 1998.

[56] Paul J., and Balmer W., "Simulation modeling", Lund: Chartwell- Bratt, 1993.

[57] Robinson S., "Successful simulation: a practical approach to simulation projects", Maidenhead: McGraw-Hill Book Company Europe, 1994.

[58] Law A., and Kelton W., "Simulation modeling and Analysis", 3d ed., McGraw-Hill, New York, 2000.

[59] England W., and Ropert S., "Application of computer simulation in health care", In: Highland HJ, Hull LG and Neilsen NR (eds), proceeding of the 1978 winter simulation conference, Institution of electrical and electronics engineering, Miami, Florida, 4-6 Dec,1978, pp 665-676.

[60] Elliott S., "Computer simulation of hospital operation: session introduction, In: Gantz D.T., Blais G.C. and Salmon S.L. (eds), Proceeding of the 1985 winter simulation conference, Institution of Electrical and Electronics Engineering ,San Francisco, California, USA , 11-13 Dec, 1985, pp 541-542.

[61] Klien, R., Dittus R., Roperts S., and Wilson J., "Simulation modeling and health care decision making", Medical Decision Making,Vol.13, 1993, pp347-354.

[62] Banks J., and Carson J., "Applying the simulation process", In: Theses A., Grant H., and Kelton W., (eds), Proceeding of the 1987 winter simulation conference. Institution of Electrical and Electronics Engineers, Atlanta, Georgia, USA, 14-16 Dec, 1987, pp 68-71.

[63] Lowery J., "Introduction to simulation in health care" , In: Charnes J.M., Morrice D.M., Burnner D.T., Swain J.J., (eds), Proceeding of the 1996 winter simulation conference, Institution of Electrical and Electronics Engineers, Colorado, California, USA, 8-11 Dec,1996, pp 78- 84.

[64] Stanridge C., "A tutorial on simulation in health care application: application and issues", In: Farrington P.A., Nembhard H.B., Sturrock D.T. and Evans G.W., (eds), Proceeding of the 1999 winter simulation conference, Institution of Electrical and Electronics Engineers, Phoenix, Arizona, USA, 5-8 Dec,1999, pp 49- 55.

[65] Shannon R., Introduction to simulation, In : Swain J., Goldsman D., Crain R. and Wilson J., (eds), Proceeding of the 1992 winter simulation conference, Institution of Electrical and Electronics Engineers, Arlington, Virginia, USA, 13-16 Dec,1992, pp 65-73.

[66] Centeno M., "An introduction to simulation modeling", In: Charnes J.M., Morrice D.M., Burnner D.T., Swain J.J., (eds), Proceeding of the 1996 winter simulation conference, Institution of Electrical and Electronics Engineers, Colorado, California, USA, 8-11 Dec,1996, pp 15-22.

[67] Seymour D., "Health care modeling and clinical practice. Theoretical exercise or practical tool?" Health Care Management Science, Vol.4, 2001, pp7-12.

[68] Hindel A., "The development and use of computer simulation models as an aid to hospital management planning", progress report 2, Department of operational research, University of Lancaster, England, 1967.

[69] Valinsky D., "Simulation, In: operations research in health care", In: Shuman L., Speas R., and Young J., (eds), Baltimore, The Johns Hopkins University press, 1975.

[70] Barnes C., Quiason J., Benson C., and McGuiness D., "Success stories in simulation in health care", In: Andradottir S., Healy K., Wither D., and Nelson B., (eds), Proceeding

of the 1997 winter simulation conference, Institution of Electrical and Electronics Engineers, Atlanta, Georgia, USA, 7-10 Dec, 1997, pp 1280- 1285.

[71] Wong A., and Au T., "A dynamic model for planning patient care in hospital", In: Proceedings of the 1970 annual conference on Applications of simulation, Institute of Electrical and Electronics Engineers, New York, USA Dec 09 - 11, 1970, pp45-51.

[72] Gove D., Hewett D., and Shahani A., "Towards a model for hospital case-load decision support", IMA Journal of Mathematics Applied in Medicine & Biology, Vol.12, 1995, pp329-338.

[73] Sepúlveda J., Thompson W., Baesler F., Alvarez M., and Cahoon L., "The use of simulation for process improvement in a cancer treatment canter", In: Farrington P.A., Nembhard H.B., Sturrock D.T. and Evans G.W., (eds), Proceeding of the 1999 winter simulation conference, Institution of Electrical and Electronics Engineers, Phoenix, Arizona, USA, 5-8 Dec, 1999, pp 1541-1548.

[74] Dumas M., "simulation modeling for hospital bed planning", simulation, Vol.43, 1984, pp69-78.

[75] Dumas M., "Hospital bed utilization: An implemented simulation approach to adjusting and maintaining appropriate levels", Health Services Research, Vol.20, 1985, pp43-61.

[76] Cohen M., Hershey J., and Weiss E., "Analysis of capacity decisions for progressive patient care hospital facilities", Health Services Research, Vol. 15, 1980, pp145-160.

[77] Harper P., "A framework for operational modeling of hospital resources", Health care management science, Vol.5, 2002, pp165-173.

[78] Harper P., and Shahani A., "Modeling for the planning and management of bed capacities in hospitals", Journal of the Operational Research Society, Vol.53, 2002, pp11-18.

[79] El-Darzi E., and Vasillakis C., "A simulation study of winter bed crisis, Health care management science", Vol.4, 2001, pp31-36.

[80] El-Darzi E.,Vasilakis C., Chaussalet T., and Millard P., "A simulation modeling approach to evaluating length of stay, occupancy, emptiness and bed blocking in a hospital geriatric department", Health Care Management Science, Vol.1, 1998, pp143-149.

[81] Vassilacopoulos G., "A simulation model for bed allocation to hospital inpatient departments", Simulation, Vol.45, 1985, pp233-241.

[82] Williams S., "How many intensive care beds are enough?" Critical Care Medicine, Vol.11, 1983, pp412-416.

[83] Ridge J., Jones, S., Nielsen M., and Shahani A., "Capacity planning for intensive care unit", European Journal of Operational Research, Vol.105, 1998, pp346-355.

[84] Kim S., Horowitz I., Young K., and Buckley T., "Flexible bed allocation and performance in the intensive care unit", Journal of Operations Management, Vol.18, 2000, pp427-443.

[85] Hancock W., Magerlein D., Storer R., and Martin J., "Parameters affecting hospital occupancy and implications for facility sizing", Health Services Research, Vol.13, 1978, pp276-289.

[86] Harris R., "Hospital bed requirements planning", European Journal of Operational Research, Vol.25, 1987, pp121-126.

[87] Huang X., "A planning model for requirement of emergency beds", IMA Journal of Mathematics Applied in Medicine & Biology, Vol.12, 1995, pp345-353.

[88] McGuire F., "Using simulation to reduce length of stay in emergency department", In: Tew J.D., Manivannan S., Sadowski D.A. and Siela A.F., (eds), Proceedings of the 1994 Winter simulation conference, Institution of Electrical and Electronics Engineers, Orlando, Florida, United States Dec 11 - 14, 1994, pp 861-867.

[89] Freedman R., "Reduction of average length of stay in the emergency room using discrete simulation", In: Anderson J.G. and Katzper M., (eds), Proceeding of 1994 simulation in health science conference, Society for computer simulation, Newport Beach, California, USA, January 1994, pp 6-8.

[90] Garcia M., Centeno M., Rivera C., and DeCario N., "Reducing time in an emergency room via a fast track" , In: Alexopoulos C., Kang K., Lilegdon W.R., and Goldman D., (eds), Proceedings of the 1995 Winter simulation conference, Institution of Electrical and Electronics Engineers, Arlington, Virginia, United States Dec 03 - 06, 1995, pp1048-1053.

[91] Lange V., "Blueprints designed to improve quality of care using simulation tool", Success stories, http:// www.medmodel.com/ stories.htm. (09 Sep 1998).

[92] Jones S., "Forecasting demand of emergency care, health care management science", Vol.5, 2002, pp297-305.

[93] Lowder B., "Durham regional saves $ 150,000 annually using simulation tool", Success stories, http:// www.medmodel.com/ stories.htm. (09 Sep 1998).

[94] Cono M., and Dawson K., "Determining the size of the Gastroenterology division expansion using simulation: A case study", In: Proceeding of the 1993 annual HIMSS conference, Chicago, USA, Vol.2, 1993, pp127-137.

[95] Lowery J., and Davis J., "Determination of operation room requirements using simulation", In: Farrington P.A., Nembhard H.B., Sturrock D.T., and Evans G.W., (eds), Proceeding of the 1999 winter simulation conference, Institution of Electrical and Electronics Engineers, Phoenix, Arizona, USA, 5-8 Dec, 1999, pp 1568-1572.

[96] Kutzdrall P., Kwak N., and Schmitz H., "Simulating space requirements and scheduling policies in a hospital surgical suite", Simulation, Vol. 27, 1981, pp163-171.

[97] Meier L., Elliot S., and Vitale F., "The use of simulation model for planning ambulatory surgery", In: Gantz D.T., Blais G.C., and Solomon S.L., (eds), Proceeding of the 1985 winter simulation conference, Institution of Electrical and Electronics Engineers, San Francisco, California, USA, 11-13 Dec, 1985, pp 558-563.

[98] Currie K, "Simulation modeling in health care facilities", In: Sheppard S., Pooch U.W. and Pegden C.D., (eds), Proceeding of the 1984 winter simulation conference, Institution of Electrical and Electronics Engineers, Dallas, Texas, USA, 28-30 Nov,1984, pp 713-717.

[99] Iskander W., and Carter D., "A simulation model for same day care facility at a university hospital", In: Nelson B.L., Kelton W.D. and Clark G.M., (eds), Proceeding of the 1991 winter simulation conference, Institution of Electrical and Electronics Engineers, Phoenix, Arizona, USA, 8-11 Dec, 1991, pp 846-853.

[100] Lange V., The benefits of simulation modeling in medical planning and medical design, In: Farrington PA, Nembhard HB, Sturrock DT and Evans GW (eds), Proceeding of the 1999 winter simulation conference, Institution of Electrical and Electronics Engineers, Phoenix, Arizona, USA, 5-8 Dec, 1999, pp 1564-1567.

[101] Amladi P., "Outpatient health care facility planning and sizing via computer simulation", In: Sheppard S., Pooch U.W., and Pegden C.D.,(eds), Proceeding of the 1984

winter simulation conference, Institution of Electrical and Electronics Engineers, Dallas, Texas, USA, 28-30 Nov, 1984, pp705-711.

[102] Centeno M., Albacete C., Terzano D., Carrillo M., and Ogazon T, "A simulation study of the radiology department at JMH", In: Joines J.A., Barton R.R., Kang K., and Fishwick P.A., (eds), Proceeding of the 2000 winter simulation conference, Institution of Electrical and Electronics Engineers, Orlando, Florida, USA, 10–13 Dec, 2000, pp 1978-1984.

[103] Clark T., and Waring C., "A simulation approach to analysis of emergency services and trauma center management, In: Theses A., Grant H. and Kelton W., (eds), Proceeding of the 1987 winter simulation conference. Institution of Electrical and Electronics Engineers, Atlanta, Georgia, USA, 14-16 Dec, 1987, pp 925-931.

[104] Draeger M., "An emergency department simulation model used to evaluate alternative nurse staffing and patient population scenarios", In : Swain J.J., Goldsman D., Crain R.C. and Wilson J.R., (eds), Proceeding of the 1992 winter simulation conference, Institution of Electrical and Electronics Engineers, Arlington, Virginia, USA, 13-16 Dec, 1992, pp 1057-1064.

[105] Lopez –Valcarcel B., and Perez P "Evaluation of alternative functional designs in an emergency department by means of simulation", Simulation, Vol.63, 1994, pp20-28.

[106] Bodtker K., Wilson L., and Godolphin W., "Simulation as an aid to clinical chemistry planning", In: Anderson J., (eds), Proceeding of the 1992 conference on simulation in health care and social services, Newport Beach, California, USA, 20-22 January, 1992, pp 15-18.

[107] Godolphin W., Bodtker K., and L. Wilson., "Simulation modeling: a tool to help predict the impact of automation in clinical laboratories", Laboratory Robotics and Automation, Vol.4, 1992, pp249-255.

[108] Badri M., and Hollingsworth J., "A simulation model for scheduling in the emergency room", Int J Opns and Prod Mgmt, Vol.13, 1993, pp13-24.

[109] Gerald W., Tesham B., and Edward U., "A simulation model for evaluating personnel schedules in a hospital emergency department", In: Charnes J.M., Morrice D.M., Burnner D.T., Swain J.J., (eds), Proceeding of the 1996 winter simulation conference,

Institution of Electrical and Electronics Engineers, Colorado, California, USA, 8-11 Dec, 1996, pp 1205-1209.

[110] Rossetti M., Trzcinski G., and Syverud S., "Emergency department simulation and determination of optimal attending physician staffing schedules", In: Farrington P.A., Nembhard H.B., Sturrock D.T. and Evans G.W., (eds), Proceeding of the 1999 winter simulation conference, Institution of Electrical and Electronics Engineers, Phoenix, Arizona, USA, 5-8 Dec, 1999, pp 1532-1540.

[111] Hashimoto F., and Bell S., "Improving outpatient clinic staffing and scheduling with computer simulation", Journal of General Internal Medicine, Vol.11, 1996, pp182-184.

[112] Swisher J., and Jacobson S., " Evaluating the design of a family practice health care clinic using discrete-event simulation", Health Care Management Science, Vol.5, 2002, pp75-88.

[113] Wilt A., and Goddin D., "Health care case study: Simulating staffing needs and workflow in an outpatient diagnostic center", Industrial Engineering, Vol.2, 1989, pp22-26.

[114] Klafehn K., "Impacts points in patient flows through radiology department provided through simulation", In: Thesen A., Grant H. and Kelton W., (eds), Proceeding of the 1987 winter simulation conference. Institution of Electrical and Electronics Engineers, Atlanta, Georgia, USA, 14-16 Dec, 1987, pp 914-918.

[115] Vemuri S., "Simulated analysis of patient waiting time in an outpatient pharmacy", American Journal of Hospital Pharmacy, Vol.41, 1984, pp1127-1130.

[116] Ishimoto K., Ishimitsu T., Koshiro A., and Hirose S., "Computer simulation of optimum personnel assignment in hospital pharmacy using a work-sampling method", Medical Inform, Vol.15, 1990, pp343-354.

[117] Bailely N., "A study of queues and appointments systems in hospital outpatient departments, with special reference to waiting times", Journal of Royal statistical Society, Vol.A14, 1952, pp185-199.

[118] Fetter R., and Thomson J., "The simulation of hospital systems", Operational Research, Vol. 13, 1965, pp689-711.

[119] Smith E., and Warner H., "Simulation of a multi-phasic screening procedure for hospital admissions", Simulation, Vol.17, 1970, pp57-64.

[120] Kachhal S., Klutke G., and Daniels E., "Two simulation applications to outpatient clinics", In: Oren T.I., Delfosse C.M. and Shubl C.M. (eds), Proceeding of the 1981winter simulation conference. Institution of Electrical and Electronics Engineers, Atlanta, Georgia, USA, 9-11 Dec, 1981, pp657-665.

[121] Smith S., Schroer B., and Shannon R., "scheduling of patients and resources for ambulatory health care", In: Highland H.J., Spiegel M.G. and Shannon R., (eds), Proceeding of the 1979 winter simulation conference, Institution of electrical and electronics engineers, San Diego, California, 3-5 Dec, 1979, pp553-562.

[122] Williams W., Covert R., and Steele J., "Simulation modeling of a teaching hospital clinic", Hospitals, Vol.41, 1967, pp71-75.

[123] Klassen K., and Rohleder T., "Scheduling outpatient appointments in a dynamic environment", Journal of Operation Management, Vol.14, 1996, pp83-101.

[124] Rohleder T and Klassen K., "Rolling horizon appointment scheduling: A simulation study", Healthcare Management Science, Vol.5, 2002, pp201-209.

[125] Ho C., and Lau H., "Minimizing total cost in scheduling outpatient appointments", Management Science, Vol.38, 1992, pp1750-1764.

[126] Ho C., and Lau H., "Evaluating the impact of operating conditions on the performance of the appointment scheduling", European Journal of Operational Research, Vol.112, 1999, pp542, 553.

[127] Swisher J., Jacobson S., Jun B, and Balci O., "Simulation of the queston physician network", In: Andradottir S., Healy K.J., Wither D.H. and Nelson B.L., (eds), Proceeding of the 1997 winter simulation conference, Institution of Electrical and Electronics Engineers, Atlanta, Georgia, USA, 7-10 Dec, 1997, pp 1146-1154.

[128] Magerlein J., and Martin J., "Surgical demand scheduling: A review", Health services Research, Vol.11, 1976, pp53-68.

[129] Murphy D., and Sigal E., "Evaluating surgical block scheduling using computer simulation", In: Gantz D.t., Blais G.C. and Solomon S.L., (eds), Proceeding of the 1985 winter simulation conference, Institution of Electrical and Electronics Engineers, San Francisco, California, USA, 11-13 Dec, 1985, pp551-557.

[130] Fitzpatrick K., Baker J., and Dave D., "An application of computer simulation to improve scheduling of hospital operating room facilities in the United State", International Journal of Computer Application in Technology, Vol.6, 1993, pp215-224.

[131] Manansang H., and Heim J., "An online simulation- based patient scheduling system", In: Charnes J.M., Morrice D.M., Burnner D.T., Swain J.J., (eds), Proceeding of the 1996 winter simulation conference, Institution of Electrical and Electronics Engineers, Colorado, California, USA, 8-11 Dec, 1996, pp1170-1175.

[132] Smith W., and JR M., "A simulation of hospital admission policy", Communication of the ACM, Vol.9, 1969, pp362-365.

[133] Hancock W., and Walter P., "The use of computer simulation to develop hospital systems", Simuletter, Vol.10, 1979, pp28-32. .

[134] Hancock W., and Walter P., "The use of admissions simulation to stabilize ancillary workloads", Simulation, Vol.43, 1984, pp88-94.

[135] Walter S., "A comparison of appointment schedules in a hospital radiology department", British Journal of Preventive and Social Medicine, Vol.27, 1973, pp160-167.

[136] Lowery J., Design of hospital admissions scheduling system using simulation, In: Charnes J.M., Morrice D.M., Burnner D.T., Swain J.J., (eds), Proceeding of the 1996 winter simulation conference, Institution of Electrical and Electronics Engineers, Colorado, California, USA, 8-11 Dec, 1996, pp1199-1204.

[137] Kraitsik M., and Bossmeyer A., "Simulation applied to planning an emergency department expansion", In: Anderson J.G., and Katzber M., (eds), 1993 SCS winter simulation multi-conference on simulation: Simulation in health care science and services, Society of computer simulation, La Jolla, California, USA, 17-20 January, 1993, pp19-27.

[138] Kirtland A., Lockwood J., Poisker K., Stamp L, and Wolfe P., "Simulating an emergency department is as much fun as..." In: Alexopoulos C., Kang K., Lilegdon W.R. and Goldman D., (eds), Proceedings of the 1995 Winter simulation conference, Institution of Electrical and Electronics Engineers, Arlington, Virginia, United States Dec 03-06, 1995, pp1039-1042.

[139] Blake J., and Carter M., "An analysis of emergency room wait time issues via computer simulation", INFOR, Vol.34, 1996, pp263-272.

[140] Shelton P., "Measuring and improving patient satisfaction", Aspen Publishers, Inc. Gaithersburg, Maryland, 2000.

[141] Paul Walley P. and Gowland B., "Completing the circle: from PD to PDSA", International Journal of Health Care Quality Assurance, Vol.17, No.6, pp349-358.

[142] Hays R., Davies A., and ware J., "Scoring the medical outcomes study patient satisfaction questionnaire": PSQIII.MOS memorandum Rand Corporation, Santa Monica, 1987.

[143] Promodel training course guidelines, promodel corporation, 2002.

[144] Centeno M., Cristina A., Terzano D, Carrillo M., and Ogazon T., "A simulation study of the radiology department at JMH". In : Joines J.A., Barton R.R., Kang K., and Fishwick P.A, eds. Proceedings of the 2000 Winter Simulation Conference, Institution of Electrical and Electronics Engineers, Orlando, Florida, Dec10 –13, 2000, PP1978 –1984.

[145] Harrell C., and Lange V., "Health care simulation modeling and optimization using medmodel", In: Peters B.A., Smith J.S., Medeiros D.J., and Rohrer M.W., eds. Proceedings of the 2001 Winter Simulation Conference, Institution of Electrical and Electronics Engineers, Arlington, Virginia, Dec 09-12, 2001, pp233–238.

[146] Harrell C., and Price R., "simulation modeling using Promodel technology", In : Chick S., Sanchez P.J., Ferrin D., and Morrice D.J., eds. Proceedings of the 2003 Winter Simulation Conference, Institution of Electrical and Electronics Engineers, New Orleans, Louisiana, Dec 07-10, 2003, pp175-181

[147] http:// www.medmodel.com

[148] Baesler F., Jahnsen H., and DaCosta M., "The use of simulation and design of experiments for estimating maximum capacity in an emergency room", In: Chick S., Sanchez P.J., Ferrin D., and Morrice D.J, eds. Proceedings of the 2003 Winter Simulation Conference, Institution of Electrical and Electronics Engineers, New Orleans, Louisiana, Dec 07–10, 2003, pp1903-1906.

[149] Mahapatra S, Koelling C., Patvivatsiri L., Fraticelli B., Eitel D., and Grove L., "Pairing emergency severity index5-level triage data with computer aided system design to improve emergency department access and throughput", In: Chick S., P.J. Sanchez P.J., Ferrin D., and D.J Morrice D.J., eds. Proceedings of the 2003 Winter Simulation

eds. Proceedings of the 2003 Winter Simulation Conference, Institution of Electrical and Electronics Engineers, New Orleans, Louisiana, Dec 07–10, 2003, pp 1907-1911.

[151] Blasak R., Starks D., Armel W., and Hayduk M., "The use of simulation to evaluate hospital operations between the emergency department and a medical telemetry unit", In: Chick S., Sanchez P.J., Ferrin D., and Morrice D.J., eds. Proceedings of the 2003 Winter Simulation Conference, Institution of Electrical and Electronics Engineers, New Orleans, Louisiana, Dec 07–10, 2003, PP 1887-1893.

[152] Centeno M, Giachetti R., Linn R., and Ismail A.,"A simulation-ilp based tool for scheduling ER staff', In: Chick S., Sanchez P.J., Ferrin D., and Morrice D.J., eds. Proceedings of the 2003 Winter Simulation Conference, Institution of Electrical and Electronics Engineers, New Orleans, Louisiana, Dec 07–10, 2003, pp1930-1938.

[153] Conway, R., "Some tactical problems in digital simulation", Management science, Vol.10, No.1, October 1963, pp.44-61

[154] Clark T., "A simulation approach to analysis of emergency services and trauma center management", In: Thesen A., Grant H., and Kelton W., (eds), Proceeding of the 1987 winter simulation conference. Institution of Electrical and Electronics Engineers, Atlanta, Georgia, USA, 14-16 Dec, 1987, pp 925-931.

[155] Templin, J.L. "Conducting the perfect emergency room study", Proceeding of the 1990 annual information and management system conference, 1990, pp 103-118.

[156] Rashed alkaabi, A. O. Abd. El Halim, and Samy Mahmoud, 'Improving Resource Allocation Efficiency in Health Care Delivery Systems", IEEE CCECE 2006 conference May 7-10, 2006, Ottawa, Canada.

Appendix (A):

(Patient Satisfaction Questionnaire)

Patient Satisfaction Questionnaire

Instructions:
Please read each statement carefully, keeping in mind the medical care you receiving right now. We are interested in your feedback about the medical care services that our hospital provides.

Department: ----------------------------------
Age: ------------------------------------
Gender: M: F:

Please indicate how strongly do you AGREE or DISAGREE with each of the following statements.

A. Access	**Strongly Agree**	**Agree**	**Uncertain**	**Disagree**	**Strongly Disagree**
1. It is easy for me to get medical care in an emergency.					
2. I am usually kept waiting for a long period of time.					
3. It is hard for me to get medical care on short notice.					
4. Where I get medical care people have to wait too long.					
5. I have easy access to the medical specialist I need.					
6. It is hard to get an appointment for care right away.					
7. I am able to get medical care whenever I need it					
8. If I need hospital care, I can get admitted easily.					

B. Convenience:	**Strongly Agree**	**Agree**	**Uncertain**	**Disagree**	**Strongly Disagree**
1. The office hours when I get medical care are convenient (good) for me.					
2. The office where I get medical care should open more hours.					
3. Places where I get medical care are well located.					

C. Communication:	**Strongly Agree**	**Agree**	**Uncertain**	**Disagree**	**Strongly Disagree**
1. Doctors are good in explaining the reason for medical tests.					
2. During my medical visits, I am always allowed to say everything that I think is important.					
3. Sometimes doctors use medical terms without explain in what they mean.					
4. Sometimes nurses use medical terms without explaining what they mean.					
5. Doctors sometimes ignore what I tell them.					
6. If I have a medical question, I can reach a doctor for help without any problem.					
7. Doctors rarely give me advice about ways to avoid illness and stay healthy.					

D. Quality of Care:	**Strongly Agree**	**Agree**	**Uncertain**	**Disagree**	**Strongly Disagree**
1. Doctors need to be more thorough in treating and examining me					
2. Sometimes, doctors make me more wonder if their diagnosis is correct.					
3. The medical staff that treats me knov about the latest medical developments.					

	Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
4. Doctors never expose me to unnecessary risk.	☝	☝	☝	☝	☝
5. Some of the doctors I have seen lack of experience with my medical problems.	☝	☝	☝	☝	☝
6. Overall, the medical care I receive is excellent.	☝	☝	☝	☝	☝
7. Doctors usually spend plenty of time with me.	☝	☝	☝	☝	☝
8. In general, nurses usually spend plenty of time with me.	☝	☝	☝	☝	☝
9. I m dissatisfy with some things about the medical care I receive.	☝	☝	☝	☝	☝
10. My doctor is very competent and well trained.	☝	☝	☝	☝	☝

F. General Satisfaction:	Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
1. I am very satisfied with the medical care I receive.	☝	☝	☝	☝	☝
2. There are some things about the medical system that need to be improved.	☝	☝	☝	☝	☝

General Comments:

Areas of Improvement:

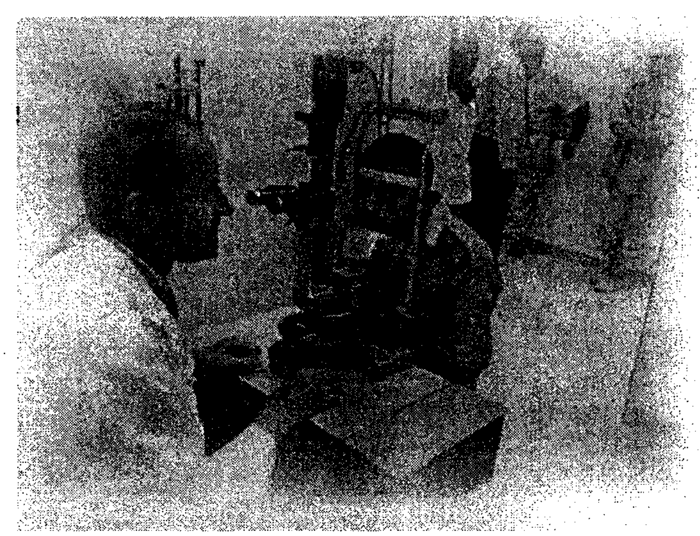
Appendix (B):

(Physicians and Employee Satisfaction Questionnaire)

Physicians and Employee Satisfaction Survey

Instructions:
Please choose the number that best reflects your response to each statement as follows:

1. Completely disagree
2. Somewhat disagree
3. Somewhat agree
4. Completely agree
5. Don't know
6. Not applicable



Please note that the term "ZH" refers to Zayed Hospital

Physicians and Employee Satisfaction Survey:

Department :

1-Completelydisagree 2-Somewhatdisagree3-Somewhatagree 4- Completely agree 5-Don'tknow6- Not applicable

Please indicate your agreement with each of the following statement

1	Overall, the work environment at ZH has changed for better over the last year.	1	2	3	4	5	6
2	I am proud to say I work at ZH.	1	2	3	4	5	6
3	I would recommend ZH as a good place to work.	1	2	3	4	5	6
4	ZH provides high quality care.	1	2	3	4	5	6
5	ZH does not provide a supportive environment for employees and physicians.	1	2	3	4	5	6
6	Within the next 3 to 5 years ZH can become one of the best Hospitals in UAE.	1	2	3	4	5	6

Please rate your level of satisfaction with each of the following aspects of your work

7	The maintenance and cleanliness of your work.	1	2	3	4	5	6
8	Your work schedule.	1	2	3	4	5	6
9	Your influence over your work schedule.	1	2	3	4	5	6
10	Your current job at ZH.	1	2	3	4	5	6

Please indicate your level of agreement with each of the following statements

11	Overall, for the work I do, I am satisfied with my pay.	1	2	3	4	5	6
12	Overall, I am satisfied with my benefits package.	1	2	3	4	5	6
13	I do not have Opportunities for advancement or promotion at ZH.	1	2	3	4	5	6

Please indicate your level of agreement with each of the following statements

		1	2	3	4	5	6
14	I feel insecure about my future employment at ZH.						

1-Completely disagree 2-Somewhat disagree 3-Somewhat agree 4- Completely agree 5-Don't know 6- Not applicable

		1	2	3	4	5	6
15	Overall, I am satisfied with the number of hours I work each week.						
16	I would prefer to remain with ZH even If I were offered a comparable job in another hospital.						

Please indicate your level of agreement with each of the following Statements

		1	2	3	4	5	6
17	ZH makes a good use of human resources available.						
18	In my work area the human resources available are used inefficiently.						
19	ZH maintains effective partnership with other health care and Social services providers for the benefits of the community.						
20	ZH conducts research that improves the quality of patients care.						
21	I have the equipment/tools I need to do my job.						
22	The-equipment/tools I use are poorly maintained.						
23	ZH has the latest equipment/tools in my field.						
25	The quality of my work suffers because of my workload.						
26	Overall, I feel physically safe when I am at ZH.						
27	I am satisfied with the support I receive for my research activities.						
28	I am satisfied with the professional practice support I receive at ZH.						

Please indicate your level of agreement with each of the following statements

29	In my day-to-day work, I can have a direct impact on the success of ZH.	1	2	3	4	5	6

30	In my work area, some of the people do most of the work while others do Enough to get by.	1	2	3	4	5	6
31	At ZH we don't work together to solve problems and explore opportunities.	1	2	3	4	5	6

1-Completely disagree 2-Somewhat disagree 3-Somewhat agree 4- Completely agree 5-Don't know 6- Not applicable

32	The people I work with put the team interests ahead of their personal interests	1	2	3	4	5	6
33	In general, in my work I receive the collaboration of physicians.	1	2	3	4	5	6
34	In general, in my work I receive the collaboration of other health care Professionals.	1	2	3	4	5	6
35	I am treated with respect by the people that I work with.	1	2	3	4	5	6
36	. ZH functions as a bilingual hospital.	1	2	3	4	5	6

Please indicate your level of agreement with each of the following statements

37	My work makes poor use of my skills and abilities.	1	2	3	4	5	6
38	My work provides me with a sense of personal accomplishment.	1	2	3	4	5	6
39	My work contributes to improving the care patients receive at ZH.	1	2	3	4	5	6
40	ZH is valued by local community.	1	2	3	4	5	6
41	Good staff performance is recognized at ZH.	1	2	3	4	5	6
42	Weak staff performance is not dealt with at ZH.	1	2	3	4	5	6
43	I am satisfied with my involvement in decision making-about patient care.	1	2	3	4	5	6

Please indicate your level of agreement with each of the following statements

44	I have a clear understanding of the overall goals of ZH.	1	2	3	4	5	6

		1	2	3	4	5	6
45	I am generally informed on a timely basis about the important developments and major decisions that affect me.						
46	Overall, I have a little understanding of what is happening at ZH outside my work area.						
47	Outside of my work area I am not interested in what is happing at ZH.						

1-Completely disagree 2-Somewhat disagree 3-Somewhat agree 4- Completely agree 5-Don't know 6- Not applicable

Please indicate your level of agreement with each of the following statements My immediate supervisor:

		1	2	3	4	5	6
48	Is responsive to my need to balance work load and personal responsibilities.						
49	Motivate me to do my best.						
50	Provides the training I need to do my job well.						
51	Helps me understand what is expected of me/my job.						
52	Helps our work area function as a team.						
53	Communicate in an honest and direct manner.						
54	Treats all his/her staff fairly.						
55	Consults with staff when making decisions.						
56	Provides timely feedback on staff suggestions.						
57	Shares important information regarding ZH and our working staff.						
58	Helps remove barriers to the success of our team.						
59	Support the continuous growth and development of staff.						

Please indicate your level of agreement with each of the following statements
Senior Management:

		1	2	3	4	5	6
60	Makes good decisions.						
61	Makes decisions in timely manner.						
62	Is talking action necessary for ZH to succeed in the future.						
63	Communicates in an honest manner.						

1-Completely disagree 2-Somewhat disagree 3-Somewhat agree 4- Completely agree 5-Don't know 6- Not applicable

		1	2	3	4	5	6
64	Understand the challenges staff face in delivering quality patient care.						
65	Has a sincere interest in the satisfaction and well being of staff.						
66	Is approachable.						
67	Acts on suggestions and/or recommendations from staff.						
68	Supports the continuous growth and development of staff.						
69	Has become more effective in the last year.						

What is the one change that would most improve your satisfaction in your job (Please write in the box)

Additional questions only for physicians

Please rate your level of satisfaction with each of the following type of resource/service

		1	2	3	4	5	6
70	The support you generally receive from other colleagues.						

Dictation Services

		1	2	3	4	5	6
71	Availability of dictation services.						
72	Ease with which dictation services are accessible.						
73	Availability of dictation results where/when needed.						

Medical Records

		1	2	3	4	5	6
74	Availability of medical records where/when needed.						

1-Completely disagree 2-Somewhat disagree 3-Somewhat agree 4- Completely agree 5-Don't know 6- Not applicable

		1	2	3	4	5	6
75	Ease with which the medical records are accessible.						

Laboratory Services

		1	2	3	4	5	6
76	Availability of laboratory services.						
77	Ease with which laboratory services are accessible.						
78	Availability of laboratory results where/when needed.						

Diagnostic Imaging

		1	2	3	4	5	6
79	Availability of diagnostic imaging services.						
80	Ease with which diagnostic imaging services accessible.						
81	Availability of diagnostic imaging results where/when needed.						

Consults

		1	2	3	4	5	6
82	Availability of consults.						

83	Ease with which consults are accessible.	1	2	3	4	5	6
84	Availability of results of consults where/when needed.	1	2	3	4	5	6

Operating Room

85	Availability of operating room time.	1	2	3	4	5	6
86	Ease of the booking mechanism for operating room times.	1	2	3	4	5	6
87	Availability of personnel where/when needed.	1	2	3	4	5	6
88	Availability of equipment where/when needed.	1	2	3	4	5	6

Clinic Time

89	Availability of clinic time.	1	2	3	4	5	6
90	Ease of the booking mechanism for clinic time.	1	2	3	4	5	6

1-Completely disagree 2-Somewhat disagree 3-Somewhat agree 4- Completely agree 5-Don't know 6- Not applicable

Nursing Support

91	Availability of nursing support.	1	2	3	4	5	6
92	Ease with which nursing support is accessible.	1	2	3	4	5	6
93	Continuity of nursing care.	1	2	3	4	5	6

Workload

94	Frequency of on call.	1	2	3	4	5	6
95	Frequency of pages.	1	2	3	4	5	6
96	Clinical responsibilities.	1	2	3	4	5	6
97	Academic/administrative responsibilities.	1	2	3	4	5	6

Tell us about yourself

Which group do you belong to?

98	1	Physicians	
	2	Nursing	
	3	Manager, Director	
	4	Administrative	
	5	Clerical	

How long have you worked at ZH?

99	1	Less than 5 years	
	2	5 to 10 years	
	3	11 to 15 years	
	4	1 to 20 years	
	5	21 to 25 years	
	6	Over 25 years	

Are you

100	Male.	
	Female.	

What is your age group?

101	Under 25	
	25 -34	
	35 - 44	
	45 - 54	
	55 - 64	
	65+	

My primary work area is:

Employees

Patients services-nursing

102	Medicine in-patients department	
	Medicine clinics (outpatient departments)	
	Surgery in-patient departments	
	Surgery clinics (outpatient departments)	
	Operation rooms	
	Psychiatry	
	Obstetrics/Gynecology (in-patient clinics)	
	Obstetrics/Gynecology (out-patent clinics)	
	Intensive care unit	
	Emergency	
	Palliative care	
	Rehabilitation	
	Other (specify)	

Professional services

103	Infection control	
	Radiation safety/diagnostic imaging/health science technology	
	Laboratory medicine	
	Pharmacy	
	Nursing professional practice	
	Other (specify):	

Support Services

104	Hotel services	
	Engineering & Operations	
	Development & Planning	
	Supply processing & distribution	
	Nutrition & food services	
	Health records	
	Admitting, patient registration	
	Human resources	
	Other (specify):	

Physicians

105	Anesthesia		Ophthalmology	
	Critical care		Psychiatry	
	Emergency		Diagnostic imaging	
	Family practice		Surgery	
	Pathology & lab medicine		Dentistry	
	Medicine		ENT	
	Obstetrics & Genecology		Other (specify):	

Appendix (C):

(Process Evaluation Forms)

Dept: Emergency **Arrival Time :** **Days:**	Shift Duty Weekday	Morning	PM Weekend	Night
Procedure	**Start Time**	**End Time**		
Registration				
Triage				
Initial Assessment				
Final Assessment and Treatment				
Observation				
Trauma				
Admission				
Discharge				
X-Ray				
X-Ray Type	**Start Time**	**End Time**		
Registration				
Normal X-ray				
Ultrasound				
Special Procedures				
MRI Safety Screening				
MRI				
Preparing MRI Room				
CT Scan				
LAB				
Division: **Sample Type:**	**Start Time**	**End Time**		

Dept: X-Ray	**Shift:**	Morning	PM	Night

Arrival time: Weekday weekend

Patient type: **With appointment or walk_ in**

Referred from:-

X-Ray				
X-Ray Type	**Start Time**	**End Time**		
Registration				
Normal X-ray				
Ultrasound				
Special Procedures				
MRI Safety Screening				
MRI				
Preparing MRI Room				
CT Scan				
Appt setting			Type of X-ray	

Dept : Ortho Clinic **Shift : Morning**		
Arrival Time: **Weekday** **Patient type: A OR W**		
Process	**Start Time**	**End Time**
Registration and Medical File Check		
Medical file request		
Initial Assessment		
Final Assessment and Treatment		
Procedures (Technician) , Casting, Dressing, Reduction etc		
Appointment registration		
Admission or discharge		
X-RAY		
X-ray Type	**Start Time**	**End Time**
Registration		
Normal X-ray		
Ultrasound		
Special Procedures		
MRI Safety Screening		
MRI		
Preparing MRI Room		
CT Scan		
Appt setting		

Dept : Family Clinic	Shift : Morning	
Arrival Time: Weekday Patient type: A OR W		
Process	**Start Time**	**End Time**
Registration &Medical File Check		
Medical file request		
Initial Assessment (by Nurse)		
Physician 1st Encounter		
Physician 2nd Encounter		
Appointment registration		
Admission or discharge		
X-RAY		
X-ray Type	**Start Time**	**End Time**
Registration		
Normal X-ray		
Ultrasound		
Special Procedures		
MRI Safety Screening		
MRI		
Preparing MRI Room		
CT Scan		
Appt setting		
LAB		
Division- : Sample Type:	**Start Time**	**End Time**