DESIGN AND IMPLEMENTATION OF A WEB-BASED HOSPITAL BED ALLOCATION SYSTEM: A CASE STUDY OF STATE SPECIALIST HOSPITAL AKURE

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ABSTRACT

There has always been a problem of poor hospital bed management for in-patients in the hospital. An easily accessible and efficient hospital bed allocation system was designed and implemented. A case study to access the current level hospital bed allocation system was carried out. The case study was carried out at State Specialist Hospital, Akure. The result of the case study showed that there are various departments in which patients are directed to base on their health issue. Various units in State Specialist Hospital, Akure include; General Male, General Female, Pediatric, Pre-natal, Labour, Post-natal, emergency, dentistry and surgical wards.

The result of the analysis of this case study served as input to the design of the proposed system. The design is able to solve an easily accessible hospital bed allocation system that will ensure that in-patients are adequately allocated a bed space in a fairly and timely manner. The system interface was designed using Microsoft visual studio. SQL SERVER 2005 was used for the database to store the data for the application. C# programming language and ASP.net was used to design the hospital bed allocation system.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

Hospital is an institution for the treatment, care, and cures of the sick and wounded, for the study of disease, and for the training of physicians, nurses, and allied health care personnel (Lippincott and Wilkins, 2006). People that visit hospital for a particular treatment are known to be a patient. The visit could be Outpatient or Inpatient. Outpatients are short visit to hospital that lasts not more than a day. While Inpatients are hospital visit that requires at least one night's stay on a ward (Roger Henderson, 2013). Ward consists of a number of beds. Bed allocation concerns the management of all processes necessary to place a patient into an appropriate vacant bed (type, location, facilities, temporary or permanent status) in the Hospital. The processes taken into consideration are the admission of a patient, length of stay, type of specialist bed (if needed) and the pending discharge date (Nicholls et al., 2007).

Some patients may change beds during a hospital stay, depending on recovery rates or rehabilitation needs, or new medical procedure needs. Immediately including these reallocations data into the management system is also critical for optimal and rapid globally viewed bed management. Within the hospital, management and staff must find a balance between the demands for available beds placed on the organisation as a whole and the demands placed on them through the needs of continuum care of the patient and emergency or greater need demands. An appropriate bed allocation is important for cost efficiency of hospitals. The management of available and appropriate beds and their occupancy levels in hospitals is an integral part of the economical and ethical management of health care (Nicholls et al., 2007).

1.2 MOTIVATION

Due to changing patient loads and demand patterns over time, assigning bed complements for various medical services in a hospital is a recurring problem facing the administrators. For a large public health care delivery system, this project presents an approach for periodically allocating and/or reallocating beds to services to minimize the expected overflows. Hospitals also have a problem with losing beds, which further complicates bed allocation processes (Nicholls et al., 2007).

The hospital system, in general, is renowned for being stretched to the limit in all areas of health care, including: Staff shortages, and a growing demand in providing sufficient hospital beds (Kirby et al., 2003).

1.3 AIMS AND OBJECTIVES

The aims and objectives of this project are to:

i. Design an hospital bed allocation model

ii. Implement the designed model in (i) above using C#

1.4 PROJECT METHODOLOGY

To achieve the objectives of this project work, a review of existing related literature and journals in related subject areas, will be carried out. The Hospital bed allocation system will be designed using a bed allocation model (BAM). The model deals with allocation of free bed space to in-patient. It does this by first checking if there are free bed space(s) in patient's ward and then picks at random a particular bed number; afterward it assigns it to a particular patient. In a case where there is no free bed space, the model directs the patient to the waiting list. It waits until there is/are free space(s); it then allocates the patient to a bed space (removing the patient from waiting list).

The model will be implemented with the aid of the following technologies:

i. VISUAL STUDIO 2010 – the integrated development environment where development takes place with the aid of XHTML and CSS.
ii. SQLSERVER 2005– a relational database will be used as the data store for the whole application. It is suitable for this application because it can hold huge amount of data and seamlessly integrates the Microsoft Framework.
iii. ASP.NET- an HTML .net tag for designing user interface.
iv. C# PROGRAMMING LANGUAGE - to code the mathematical model.

1.5 EXPECTED CONTRIBUTION TO KNOWLEDGE

i. It will provide new knowledge that user can act upon.
ii. It will provide best option that can optimally ensure sufficient hospital bed.
iii. It shows the merge or bridge between biological science and computing in ensuring hospital bed allocation system.

CHAPTER TWO

LITERATURE REVIEW

2.0. INTRODUCTION

The Designing of hospital bed allocation system requires review of background and relevant literature covering hospital management, bed allocation system, queuing system and most importantly related works in the design and modelling of hospital bed allocation system.

2.1. Hospital Management

Hospital management is concerned with the organization, coordination, planning, staffing, evaluating and controlling of health services for the masses. Medical establishments such as hospitals, clinics, rehabilitation centres and so on are looked upon as edifices of hope by the diseased and the ill. Like any other business, medical establishments are organized institutions. They follow complex processes and need efficient man-power to manage these processes. The primary objective is to provide quality healthcare to people and that too in a cost-effective manner. Professional hospital management have proven how institutions can be managed proficiently, economically and successfully in a given time period (Jagran, 2011). Hospital Management provides a direct link between healthcare facilities and those supplying the services they need. This procurement and reference resource provides a one-stop-shop for professionals and decision makers within the hospital management, healthcare and patient care industries (Net Resource International, 2012).

Hospital Management is a new theory in management faculty. Earlier a senior doctor used to perform the role of a hospital manager. However, nowadays everything demands a specialist. Almost all the things related to hospital have changed. Many categories concerning medical sciences and hospital have altered totally. There are various types of hospitals today, including ordinary hospitals, specialty hospitals and super specialty hospitals. The categories are regarding to the types of facilities they offer to the people. Eligible professionals are needed for the smooth operating of a hospital. Various courses and training programs have been developed to find out eligible hospital managers. Such professionals are well trained to solve the rising challenges and specific necessities of modern day hospitals. The Hospital Management courses are open to non-medical background graduates also.

2.2. Bed Allocation System

Bed allocation concerns the permanent number of beds assigned to the different medical specialties in a hospital. An appropriate bed allocation is important for cost-efficiency of hospitals. Too few beds assigned to a specialty may lead to customer assignments to units with inappropriate equipment and inadequate staff training. This, in turn, would likely result in lower quality of care. Further, too many beds increases costs through an underutilization of resource (Lapierre et al, 1999).

Because hospital beds are economically scarce resources, there is naturally pressure to ensure high occupancy rates and therefore a minimal buffer of empty beds. However, because the volume of emergency admissions is unpredictable, hospitals with average occupancy levels above 85 per cent "can expect to have regular bed shortages and periodic bed crises. Shortage of beds can result in cancellations of admissions for planned (elective) surgery, admission to inappropriate wards (medical versus surgical, male versus female etc.), delay admitting emergency patients, and transfers of existing inpatients between wards, which "may add a day to a patient’s length of stay (Nicholls et al, 2007).

One of the major problems within a hospital environment is dealing with the bottleneck of patient allocation and the availability of beds. Through increased public scrutiny there is also a greater degree of accountability required from health care professionals with regard to facilities management and information administration. Hospitals are running at peak capacity which almost guarantees queuing in the emergency department for available beds and other critical inpatient services. Bed availability is significant as a bed can be viewed as "one of the most fundamental inputs in the provision of acute health care". The processes taken into consideration are the admission of a patient, length of stay, type of specialist bed (if needed) and the pending discharge date. Some patients may change beds during a hospital stay, depending on recovery rates or rehabilitation needs, or new medical procedure needs. Immediately including these reallocations data into the management system is also critical for optimal and rapid globally viewed bed management. Within the hospital, management and staff must find a balance between the demands for available beds placed on the organisation as a whole and the demands placed on them through the needs of continuum care of the patient and emergency or greater need demands (Nicholls et al, 2007). To date, hospitals approach the bed allocation of patients and their requirements at a very basic appraisal level. Bed allocation decisions are either on a once daily basis or a reactive need-by-need basis, requiring the time and skill of a variety of fully informed staff members or managers to complete this task. However, a hospital environment has a varied and dynamic changing staff population attending patient throughout continuing 24-hour periods. Major patient information systems in hospitals have similar applications aimed at assisting medical and administrative staff with patient administration (Nicholls et al, 2007).

Bed allocation System is designed to help hospital staff deliver high levels of care to patients by providing real-time information to bed managers, ward staff, doctors and optimising communication efficiency between all staff. A system for the healthcare sectors include in-patient management systems to help ward staff manages patient traffic and bed allocation within a hospital. Such systems make the daily process of patient and bed management easier; improve staff efficiency by saving time and helps management meet hospital performance targets. Features of such a system can include:

i. Categorised bed requests for urgent beds and therefore reduce wait times.
ii. A real-time view of the current state of beds in all wards.
iii. Direct transfer to certain wards as needed.
iv. Queuing patients for beds to improve patient care.

2.2.1 Bed Allocation in Intensive Care Unit (1CU)

Managing the beds in an ICU is a difficult problem that lacks a single solution to please everybody. New demands for ICU care and the service times required by its current residents are stochastic, which makes it impossible to guarantee admission to all deserving patients. When no beds are unoccupied, the administrator takes the path of least resistance. That path exploits the fact that there are some patients whose admission can be postponed. The latter patients are those scheduled for elective surgery. In their case the surgery is cancelled, which inconveniences the surgeon and the attending staff, to say nothing of the patient. It is therefore incumbent upon the administrator to make the most effective use of the extant bed capacity (Seung-Chul Kim et al, 2000).

One suggestion for achieving this goal at minimal cost is to reserve some beds for the exclusive use of the elective-surgery patients. In dealing with this suggestion, the administrator faces two major issues. First, it is necessary to evaluate the various proffered bed-reservation schemes on any number of performance criteria, which creates a multiple-objective decision-making problem. Second, it is necessary to communicate the results, and the reasons for either rejecting those schemes or for putting one in place, to those higher up in the managerial hierarchy, as well as to the operating surgeons and the ICU physicians (Seung-Chul Kim et al, 2000).

The beds of an intensive care unit (ICU) are a scarce resource. Stochastic patient demands for these beds and stochastic service times in their utilization make managing that resource a complex problem lacking an easy solution. Operations managers make repetitive decisions subject to capacity constraints that are not readily relaxed. Thus, utilizing the extant capacity optimally is an operational imperative. Nowhere is this imperative better exemplified than in a hospital's intensive care unit (ICU) where the lives of the hospital's most critically ill patients are at stake. Expanding capacity, the number of beds in the unit, is not an option, as ICU care is an unusually expensive therapy. Reducing capacity is not an option either, as this would risk deserving patients being denied admission to the unit or released prematurely. Patients, however, are only one of several constituencies to which the administrator is accountable, and the preferences of those constituencies in the prioritization process often conflict. One especially prominent conflict in most hospital is between the operating surgeons and the ICU physicians. This is a potential conflict in any hospital that has an ICU. The basis for the conflict is that the surgeons must schedule elective surgeries and the operating theatre well in advance, and assume there will be an empty bed in the ICU, whereas the ICU physicians set their admissions priorities based upon all the applicants' needs (Seung-Chul Kim et al, 2000).

The administrator often must deny admission to an elective-surgery (ES) patient, thereby forcing the surgeon to cancel and reschedule the surgery, which can have several negative consequences. First, this can wreak havoc with both the surgeons' schedules and those of the supporting staff, and waste the time of some highly skilled people. Second, the cancellations require changes in the operating theatre's schedule. Last, they can cause great psychological stress on patients, few of whom view their own surgeries as being ‘‘minor’’. To resolve the conflict, the surgeons have proposed reserving some ICU beds exclusively for elective-surgery (ES) patients. Though blatantly self-serving, this is not necessarily a bad idea.

Indeed, some form of reservation strategy might be a very good idea that offers the administrator a way out of a very ticklish managerial situation. But lives rather than personal sensibilities are involved in the bed-reallocation process (Seung-Chul Kim et al, 2000).

2.2.1 Bed Allocation in Emergency Unit

Overcrowding and long waits in hospital emergency departments have been common complaints for a number of years. Both impact the quality of patient care. The public suspects that the main underlying causes are the inappropriate use of emergency departments by walk-in patients with minor medical ailments, and poor management by hospitals, including understaffing. Although these are contributing factors, our research indicated that the lack of available in-patient beds at the hospitals, requiring admitted patients to be housed in the emergency departments, may well have an even greater impact on overcrowding and long wait times. This lack of available in-patient beds is influenced by two main factors: hospital beds being occupied by patients who are awaiting alternative care in a community-based setting, and less-than optimal practices by hospitals in managing and freeing up in-patient beds. The effectiveness of emergency departments is heavily dependent on other hospital departments and specialists (Ministry of Health and Long-Term Care, 2010).

The timeliness of accessing specialist consultations and diagnostic services was having an impact on emergency patient flow. Also, limited hours and types of specialists and diagnostic services available on-site were key barriers to efficient patient flow. Not being able to move patients requiring admission into beds in an in-patient unit is one of the key causes of delays in treating emergency-department patients. Emergency department patients admitted to in-patient units spent on average about 10 hours waiting in emergency departments for in-patient beds, but some waited as long as 26 hours or more. Delays in transferring patients from emergency departments to hospital beds frequently occurred because empty beds had not been identified or hospitals room cleaned on a timely basis. It was reviewed that paramedics often had to stay in emergency departments for extended periods of time and care for their patients while they waited for an emergency-department bed or until emergency-department nurses could accept the patients (Ministry of Health and Long-Term Care, 2010).

It was noted that cases where ambulance crews waited up to three hours for their patients to be attended to, result in fewer or no ambulances being available to respond to new emergency calls in the community. Emergency departments rely on diagnostic services to assist physicians in performing comprehensive assessments of patients. Prompt requests for and reporting of diagnostic results are important to speed up decision-making, which is crucial for emergency-department patients. The key indicator of the timeliness of diagnostic services is "diagnostic-turnaround time," which measures the time from the emergency department ordering diagnostic tests to the results becoming available. "Time-to-in-patient-bed" measures the time from an emergency-department physician deciding to admit the patient to the hospital's in-patient area to the patient's actual departure from the emergency department (Ministry of Health and Long-Term Care, 2010).

It was noted that delays were often caused by lengthy periods of time during which in-patient by beds were empty—commonly referred to as "bed empty time. One hospital recognized the importance of this issue and specifically used three systems to track bed empty time. The House-keeping department's system monitored bed-cleaning times; the emergency-department system tracked patient movement in the emergency department; and the in-patient unit's bed tracking board monitored bed availability. Although this approach provided useful information, better integration was required to ensure that bed cleaning was initiated soon after a bed became available and that, once the cleaned bed was ready, the next patient was admitted in a timely manner. It was found that the average bed-empty time in this hospital to be about 5.5 hours (Ministry of Health and Long-Term Care, 2010).

2.2.3 Bed Allocation in Surgical Unit

The surgical centre has a fixed number of operating rooms, which are shared and utilized by all surgeon groups to perform surgeries only for elective patients. The operating rooms are assigned to various surgeon groups in a timed fashion. Once a room is assigned to a surgeon group on a block, it will be utilized exclusively by the assigned surgeon group to operate on its planned patients. If there are not enough planned patients in the corresponding waiting queue, normally the operating room will not be utilized completely. Actually, scheduling other unplanned patients can improve the operating rooms utilizations, but simultaneously generates different bed demands in the ward and definitely affects the bed occupancy and the patient service. Therefore, experiments assume that unplanned patients cannot be operated on. If the scheduled surgeries run out of the assigned blocks due to the variable surgery time, overtime is allowed to finish the scheduled surgeries. Overtime to some extent is common in most hospitals and therefore it is accepted somehow (Guoxuan Ma and Erik Demeulemeester 2010).

Moreover, overtime can avoid the cancellation of the scheduled surgeries. The stochastic operating time, which only affects the operating rooms utilizations, is simplified here. Actually, the operating time of each patient is assumed to be constant and equal to the expected surgery duration of its patient group. In addition, each block is assumed to be 8 hours, but may be extended in the case of flexible surgery blocks. Operating rooms are only open from Monday to Friday, but closed in the weekend. The surgeon groups are assumed to be always available during their assigned operating rooms blocks (Guoxuan Ma and Erik Demeulemeester 2010).

2.3 QUEUEING SYSTEM

Queue represents a certain number of customers waiting for service (of course the queue may be empty). Queuing theory is the mathematical study of waiting lines (or queues) and generally considered a branch of operations research because the results are often used when making business decisions about the resources needed to provide service. It is applicable in a wide variety of situations that may be encountered in business, commerce, industry, public service, engineering and healthcare. In supermarkets and in banks queues form when there are insufficient server units to meet the demand for service. Similarly, in hospitals, the queues form when there are insufficient beds available to admit ill people. In supermarkets and in banks customers can go elsewhere. But sick people have no alternative options: they just have to wait when the lack of sickbeds occurs.

A queuing model is used to determine the main characteristics of the access of patients to hospital, such as mean bed occupancy and the probability that a demand for hospital care is lost because all beds are occupied. Moreover, this technique is used for optimising the number of beds in order to maintain an acceptable delay probability at a sufficiently low level, and a way of optimising the average cost per day by balancing costs of empty beds against costs of delayed patients. Element of a single-queue queuing system is shown below:

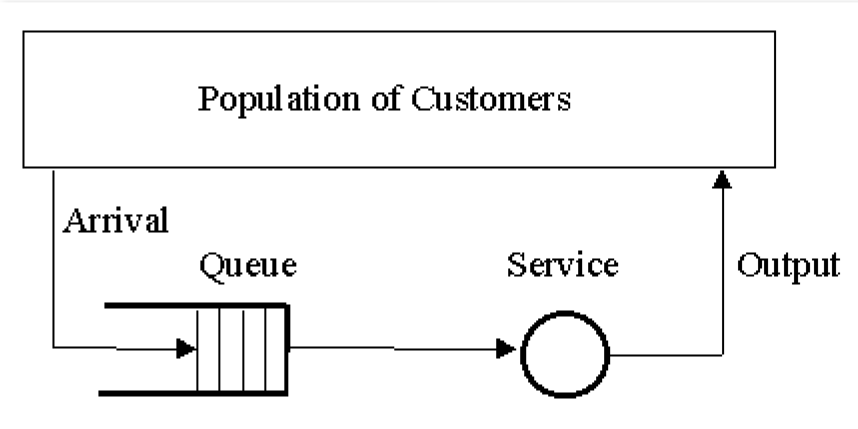


Figure 1

Figure 1: Elements of a single-queue queuing System

Population of Customers- can be considered either limited (closed systems) or unlimited (open systems). Unlimited population represents a theoretical model of systems with a large number of possible customers (a bank on a busy street, a motorway petrol station). Example of a limited population may be a number of processes to be run (served) by a computer or a certain number of machines to be repaired by a service man. It is necessary to take the term "customer" very generally. Customers may be people, machines of various nature, computer processes, telephone calls, etc.

Arrival- defines the way customers enter the system. Mostly the arrivals are random with random intervals between two adjacent arrivals. Typically the arrival is described by a random distribution of intervals also called Arrival Pattern.

Queue- represents a certain number of customers waiting for service (of course the queue may be empty). Typically the customer being served is considered not to be in the queue. Sometimes the customers form a queue literally (people waiting in a line for a bank teller). There are two important properties of a queue: Maximum Queue Size and Queuing Discipline.

Maximum Queue Size (also called System capacity) is the maximum number of customers that may wait in the queue (plus the one(s) being served). Queue is always limited, but some theoretical models assume an unlimited queue length. If the queue length is unlimited, some customers are forced to renounce without being served.

i. Queuing Discipline represents the way the queue is organised (rules of inserting and removing customers to/from the queue). There are these ways:

i. FIFO (First In First Out) also called FCFS (First Come First Serve) - orderly queue.
ii. LIFO (Last In First Out) also called LCFS (Last Come First Serve) - stack.
iii. SIRO (Serve In Random Order).
iv. Priority Queue that may be viewed as a number of queues for various priorities.

Many other more complex queuing methods that typically change the customers' position in the queue according to the time spent already in the queue, expected service duration, and/or priority. These methods are typical for computer multi-access systems.

Service- represents some activity that takes time and that the customers are waiting for. Again take it very generally. It may be a real service carried on persons or machines, but it may be a CPU time slice, connection created for a telephone call, being shot down for an enemy plane, etc. Typically a service takes random time. Theoretical models are based on random distribution of service duration also called Service Pattern. Another important parameter is the number of servers. Systems with one server only are called Single Channel Systems; systems with more servers are called Multi Channel Systems.

Output- represents the way customers leave the system. Output is mostly ignored by theoretical models, but sometimes the customers leaving the server enter the queue again ("round robin" time-sharing systems).

2.4 RELATED WORKS

Sreenath et al. (2010), Worked on Operating Room Allocating Using Mixed Integer Linear Programming (MILP). They emphasised that in many hospitals, a large percentage of patients undergo some type of surgery when admitted or during their stay in a hospital. They stated further that it is ideal that a surgery is performed as soon as it is requested or judged in order to reduce a patient‘s length of stay and also for the sake of the patient‘s health.

It was discovered that Public hospitals are non-profit organizations, and their primary operational objective is to provide medical services to their patients at a reasonable cost. They stressed further that a significant amount of time and resources are invested in operating theatres.

Their aim focuses on minimizing patients' length of stay waiting for their surgery by developing a methodology for allocating operating room capacity to different medical specialties.

They first presented the mixed integer programming (MIP) model for operating room capacity allocation to minimize inpatients' length of stay. They developed a basic model with two variants. The basic model was made up of constraints (e.g. maximum number of hours allocated to each specialty, surgeon and staff availability). The first variant of the model brings in the emergency situations that could arise for each specialty at the hospital. The second variant considers the post-operative care for the patient at the hospital. The model output gives optimized allocation of operating rooms to each speciality for each day. The model was simulated using MATLAB.

The major drawback in their work was that the optimization part of their model does not account for uncertainty in the problem parameters. Therefore it could perform poorly in practice when there are high variances associated with surgery length and volatile patient arrival patterns.

A.G. Nicholls et al. (2007), Worked on Innovative Hospital Bed Management Using Spatial Technology. They found out that some patients may change beds during a hospital stay, depending on recovery rates or rehabilitation needs, or new medical procedure needs. They stated further that the management and staff must find a balance between the demands for available beds placed on the organisation as a whole and the needs of continuum care of the patient and emergency demands.

It was discovered that existing hospitals systems rely on a large number of diverse methods to gather and collate patient and patient related information. The dissemination of this information does not enable the best informed and accurate decisions for planning and managing bed allocation.

Their main focus was to investigate how the application of GIS can benefit the health care industry and provide a simple universal graphical output system applicable and useful to all levels of medical careers in the hospital environment.

The development of a GIS was visualized as firstly providing a practical and flexible tool that aids administrative and medical staff with the planning and management of bed numbers, types and location for the allocation to in-patients. Secondly, using a geographical format would allow bed data to be displayed in a visual layout, in real-time, in the exact location within a room, ward or floor; plus the added capability of intuitive access to attached patient records via the bed symbol.

Ling Gao et al. (2010), introduced a methodology for modeling sickbed allocation problems with uncertain length of stay for each patient. They emphasised that in hospitals, the queues form when there are insufficient beds available to admit ill people, and sick people have to wait until free bed is available. They stated further that when a patient arrives, he/she enter a queuing system and the service system was divided into three phases including waiting sickbed, preoperative preparation and postoperative recovery. After that, the patient leaves the system.

They discovered that bed crisis sometimes appears in hospitals and stressed further that the crisis is usually attributed to factors such as the bad weather, influenza, older people, geriatricians, and lack of cash or nurse shortages.

Their design aimed to develop a methodology that will effectively reduce the patients' time in queue, thus can improve the public satisfaction to the health service.

Two uncertain bed allocation models are presented. Hybrid intelligent algorithm is employed for solving these models. Finally, numerical example is provided to demonstrate the feasibility of the proposed algorithm.

Arun Kumar and John Mo (2010), describes three bed prediction models in aiding hospital planners to anticipate bed demand so as to manage resources efficiently. They emphasised that Over-crowding is perhaps the most common scene that people see in the Emergency department of a Hospital. They stated further that the ability to forecast the random arrival patterns would definitely be the key solution to over-crowding problems.

It was discovered that healthcare providers worldwide have thus been under tremendous pressures and obtaining demerit for failing to plan effectively. They stressed further that the random arrival pattern of patients may somehow mislead healthcare planners, and thus causing them to underestimate the resources that are required within the hospital.

Their design aimed to provide useful tools for bed management unit in planning usage of beds and predict likely requirements for other resources during pandemic outbreak so as to solve the problem of overcrowding.

The objectives of this study were achieved through the development of bed prediction models using three different techniques to aid bed management in planning resources. The regression models have sufficient predictive ability to allow hospital planners to forecast the following week's average occupancy. The Poisson bed occupancy model can help bed planners in estimating bed occupancy and to allocate optimal number of beds based on length of stay and admissions data. Lastly, the simulation model developed using Arena has provided a valuable tool for predicting following week's bed occupancy level.

CHAPTER THREE

SYSTEM ANALYSIS AND DESIGN

3.0 INTRODUCTION

This chapter deals with the system analysis and design. It entails the full description of state specialist hospital, Akure bed allocation system and the system architecture which composes of several components: The implementation language, application system architecture, bed allocation model (BAM), application flow Chart and, database schema.

3.1 REVIEW OF CASE STUDY: STATE SPECIALIST HOSPITAL, AKURE BED ALLOCATION SYSTEM

State Specialist Hospital, Akure Bed Allocation System is a system that dynamically allocates bed space to hospital patient(s). The system uses a bed allocation model (BAM) to assign bed space to in-patience (admitted patience). Beds are located at the level of hospital ward which is based on hospital units. State Specialist Hospital, Akure has various departments in which patients are directed to base on their health issue. Various units in Akure State Specialist Hospital include;

I. General unit (Male and Female ward)

The general unit consists of both the male and female wards. The general unit is different from all other units in the hospital because patients admitted have common diseases such as malaria, typhoid, fever etc. There are at least fifteen beds each in both the male and female ward in State Specialist Hospital, Akure.

II. Surgical unit

The surgical unit is the actual operating rooms, where surgical procedures are performed. All operating rooms have an operating table that can be adjusted to accommodate the surgical procedure and facilitate the use of sophisticated monitoring equipment. Instruments and equipment, such as lasers or television screens, are brought into the operating room as needed. There are at least ten beds in the surgical unit in State Specialist Hospital, Akure.

III. Paediatric unit (Children's ward)

The paediatric unit admits only children and is equipped with instruments and machines that are suitable for the small size of its patients. State Specialist Hospital, Akure allows a parent to stay in the child's room during a hospital stay. There are at least ten beds in the Paediatric unit in State Specialist Hospital, Akure.

IV. Dentist unit

The dentist unit specializes in the diagnosis, prevention, and treatment of diseases and conditions of the oral cavity. The dental team includes dental assistants, dental hygienists, dental technicians, and dental therapists. There are at least five beds in the Dentist unit in State Specialist Hospital, Akure.

V. Accident and Emergency unit

The accident and emergency department is staffed 24 hours a day by doctors and nurses who have been trained to diagnose health problems quickly. These doctors and nurses perform medical or surgical treatments that stabilize a patient's condition so that the patient can be moved to another part of the hospital for additional care. When the emergency room is crowded with patients, emergency department staff identify and respond immediately to the most seriously ill or injured patients. There are at least fifteen beds in the Accident and Emergency unit in State Specialist Hospital, Akure.

VI. Maternity unit.

The maternity unit, also found in many hospitals, offers delivery rooms where a pregnant woman stays for the birth of her baby. The maternity unit is divided into three units: Pre-natal unit where a pregnant woman stays before delivery, Labour unit where the delivery takes place and Post-natal unit where the woman stays after the delivery. There are at least six beds in the Pre-natal unit, three beds in the Labour unit and twelve beds in the Post-natal unit in State Specialist Hospital, Akure.

3.2 SYSTEM ARCHITECTURE

Three tiers architecture is composed of three layers: the user interface layer, the application logic layer and the database layer. The three-tier architecture aims to solve a number of recurring design and development problems, hence, to make the application development work more easily and efficiently. The interface layer in the three-tier architecture offers the user a friendly and convenient entry to communicate with the system while the application logic layer performs the controlling functionalities and manipulating the underlying logic connection of information flows; finally, the data modelling job is conducted by the database layer, which can store, index, manage and model information needed for this application (Shu-Ching Chen, 2010). The three layers of the three tiers architecture is summarized below:

User Interface Tier: The first tier is the user interface tier. This tier manages the input/output data and their display. The user interface tier contains HTML components needed to collect incoming information and to display information received from the application logic tiers (Shu-Ching Chen, 2010).

Application Logic Tier: The application logic tier is the middle tier, which bridges the gap between the user interface and the underlying database, hiding technical details from the users (Shu-Ching Chen, 2010).

Database Tier: The database tier is responsible for modelling and storing information needed for the system and for optimizing the data access. Data needed by the application logic layer are retrieved from the database, and then the computation results produced by the application logic layer are stored back in the database. Since data are one of the most complex aspects of many existing information systems, it is essential in structuring the system. Both the facts and rules captured during data modeling and processing are important to ensure the data integrity (Shu-Ching Chen, 2010). Below is the Diagram of Three Tiers Architecture:

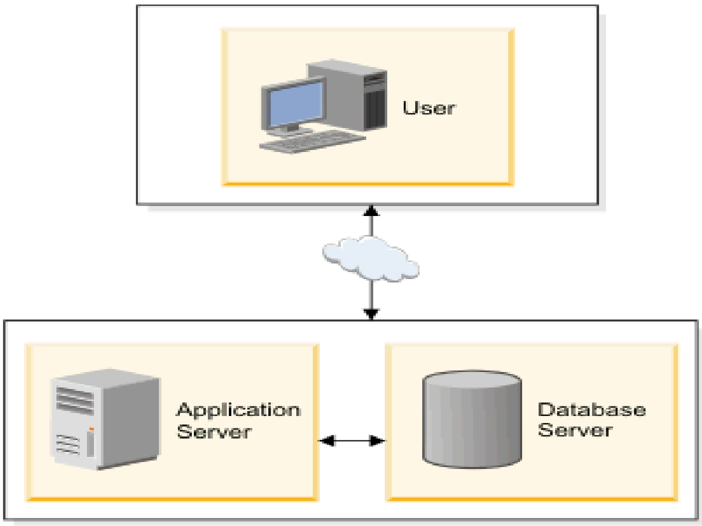


Figure 3.1: 3-tiers Architecture

3.2.1 IMPLEMENTATION LANGUAGE

The Implementation Language contains the tools used in the development of the state specialist hospital bed allocation system, akure. This include: C# programming language - to code the mathematical model and simulate it. The .net framework - bedrock on which this application is implemented. Asp.net- an HTML .net tag for designing user interface. SQL server – a relational database used as the data store for the whole application.

3.2.1.1 C# PROGRAMMING LANGUAGE

C# (pronounced C-sharp) was released in July 2000 at the Microsoft Professional Developers Conference in Orlando, Florida. It is a new programming language designed for building a wide range of enterprise applications that run on the .NET Framework. It is an Evolution of Microsoft C and Microsoft C++. C# is simple, modern, type safe, and object oriented. C# code is compiled as managed code, which means it benefits from the services of the common language runtime. These services include language interoperability, garbage collection, enhanced security and improved versioning support.

C# is introduced as Visual C# in the Visual Studio.NET suite. It is an object oriented programming language that deals with inheritance, encapsulation and polymorphism. The library for Visual C# programming is the .NET Framework.

3.2.1.2 .NET FRAMEWORK

C# programs runs on the .NET Framework, an integral component of windows that includes a virtual execution system called the common language runtime (CLR) and a unified set of class libraries. The CLR is the commercial implementation by Microsoft of the common language infrastructure (CLI), an international standard that is the basis for creating execution and development environments in which languages and libraries work together seamlessly (Matthew MacDonald, 2007).

Source code written in C# is compiled into an intermediate (IL) that conforms to the CLI specification. The IL code such as bitmaps and strings, are stored on disk in an executable file called an assembly, typically with an extension of .exe or .dll. An assembly contains a manifest that provides information about the assembly’s types, version, culture, and security requirements (Matthew MacDonald, 2007).

When the C# program is executed, the assembly is loaded into the CLR, which might take various actions based on the information in the manifest. Then, if the security requirements are met, the CLR performs just in time (JIT) compilation to convert the IL code to native machine instruction. The CLR also provides other services related to automatic garbage collection, exception handling, and resource management. Code that is executed by the CLR is sometimes referred to as “managed code,” in contrast to “unmanaged code” which is compiled into native machine language that targets a specific system. The following diagram illustrates the compile-time and run-time relationships of C# source files, the .NET Framework class libraries, assemblies, and the CLR (Matthew MacDonald, 2007). The diagram of the .NET Framework Architecture is below:

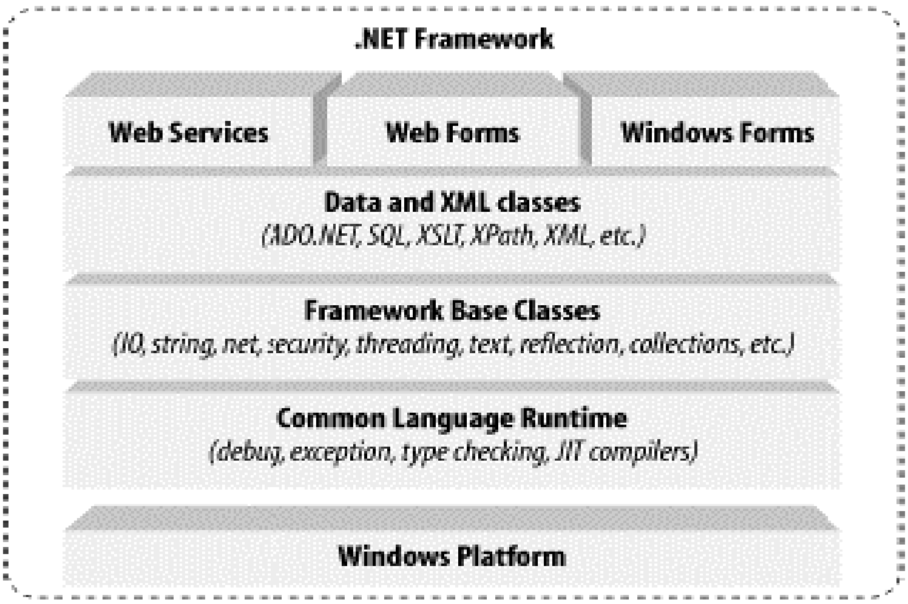


Figure 3.2: .NET Framework Architecture

3.2.1.3 ASP.NET

ASP.NET - an acronym for Active Server Pages is a bundle of .NET classes used to create Web-based, client-side (Web Form) and server-side (Web Service) applications. It was first released in January 5, 2002 with version 1.0 of the .NET Framework, and is the successor to Microsoft's Active Server Pages (ASP) technology. ASP.NET is built on the Common Language Runtime (CLR), allowing programmers to write ASP.NET code using any supported .NET language. ASP.NET pages are normally created in C#, VB.NET, or another .NET language (Chris Hart et al, 2006).

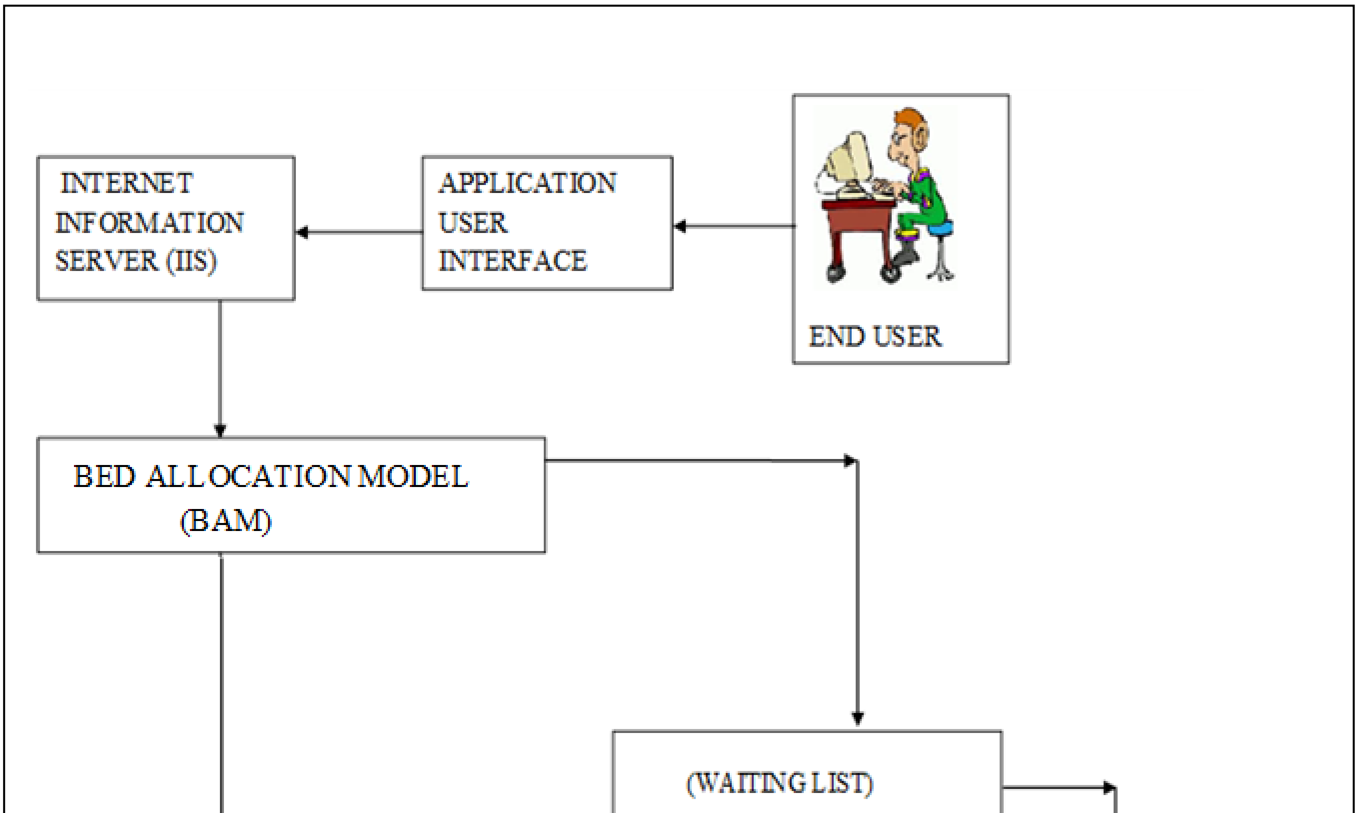
ASP.NET Web Application lets you build dynamic websites using a familiar drag-and-drop, event-driven model.ASP.NET simplifies developers' transition from Windows application development to Web development by offering the ability to build pages composed of controls similar to a Windows user interface (Chris Hart et al, 2006).

3.2.1.4 MICROSOFT SQL SERVER

SQL - an acronym for Structured Query Language is a standard language used for querying, updating, and managing relational database. Microsoft SQL Server is a comprehensive database platform that provides secure and reliable storage for both relational and structured data, enabling one to build and manage high-performance data applications. SQL Server's close integration with Microsoft Visual Studio, the Microsoft Office System, and a suite of new development tools set SQL Server apart from other database engines. This system allows developers to build, debug, and operate applications faster than ever before (Sikha S.B et al, 2006).

SQL Server can be installed on small machines using Microsoft Windows as well as on large servers. In recent years, the computer industry has seen a dramatic increase in the popularity of relational databases and multiuser databases, and the computer industry needs application developers and people who can write SQL code efficiently and correctly for relational and multiuser databases (Sikha S.B et al, 2006).

3.2.2 APPLICATION SYSTEM ARCHITECTURE



3.2.3 BED ALLOCATION MODEL (BAM)

Let T represents universal set containing all the beds in a ward, F represents set of free bed space in a ward, P represents set of occupied bed space in a ward such that:

$T = \{t_1, t_2, t_3, \ldots, t_n\}$

$F = \{f_1, f_2, f_3, \ldots, f_n\}$

$P = \{p_1, p_2, p_3, \ldots, p_n\}$

$F \subseteq T$ (F is a proper subset of T)

$P \subseteq T$ (P is a proper subset of T)

$T = \{F \cup P\}$ (T is the union of F and P)

Let λ represents number of free bed space in a ward, β represents number of occupied bed space in a ward, Φ represents the total number of beds in a ward, hence:

$$\lambda = n(F) \quad \ldots 3.1$$

$$\beta = n(P) \quad \ldots 3.2$$

$$\Phi = n(T) \quad \ldots 3.3$$

$$\Phi = \lambda + \beta \quad \ldots 3.4$$

A single allocation of a patient where $\lambda > 0$ will update the variables as follows:

$$\lambda = \lambda - 1 \quad \ldots 3.5$$

$$\beta = \beta + 1 \quad \ldots 3.6$$

A single de-allocation of a patient where $\beta > 0$ will update the variables as follows:

$$\lambda = \lambda + 1 \quad \ldots 3.7$$

$$\beta = \beta - 1 \quad \ldots 3.8$$

A single addition of a patient to the waiting list where $\lambda = 0$ will update the variables as follows:

Let Q represents total number of patient in the waiting list, hence:

$$Q = Q + 1 \quad \text{where } Q \geq 0 \quad \ldots 3.9$$

$$\beta = \Phi \quad \ldots 3.10$$

$$\lambda = 0 \qquad \ldots 3.11$$

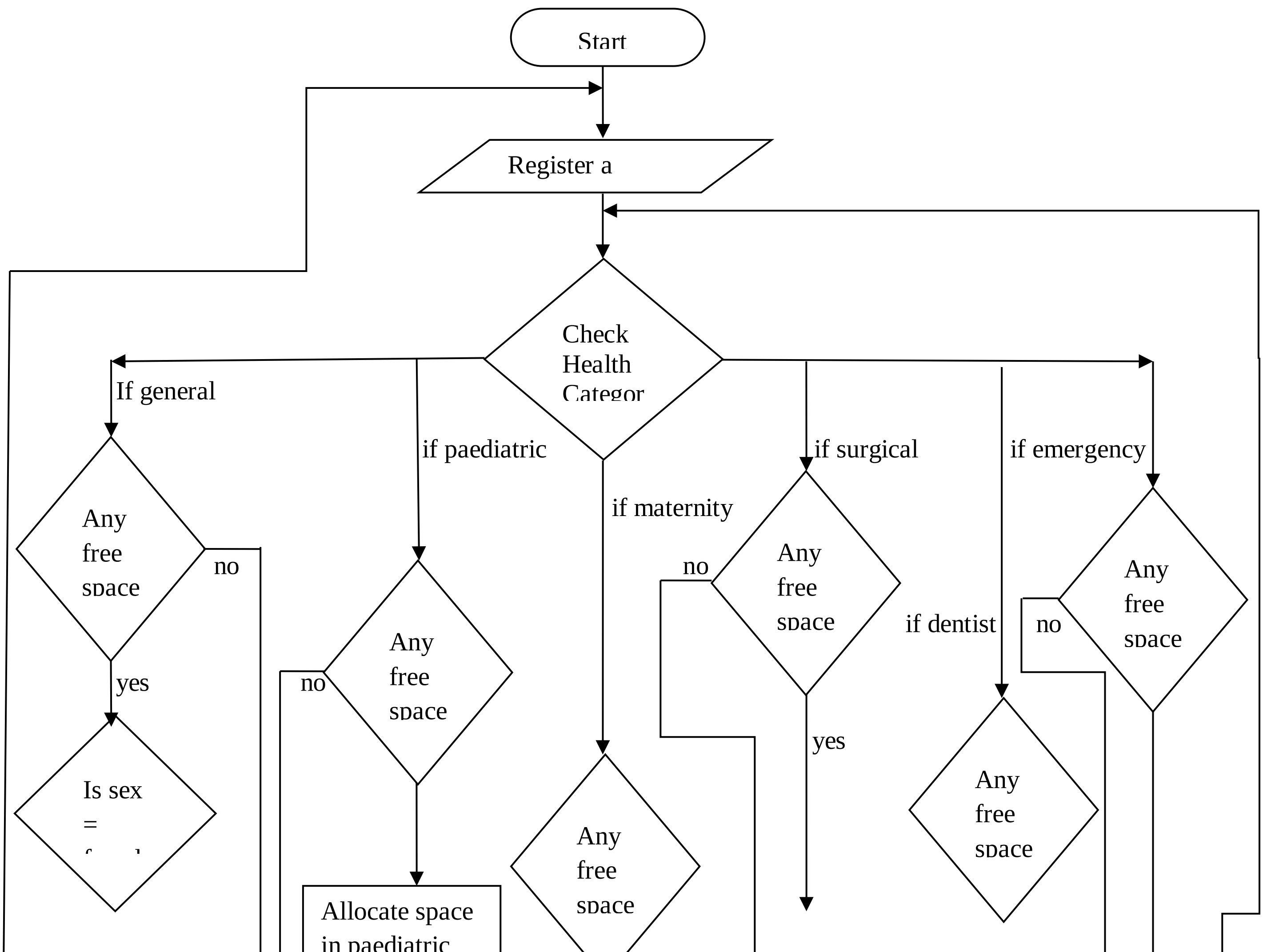
A single removal of a patient to the waiting list where $\lambda > 0$ will update the variables as follows:

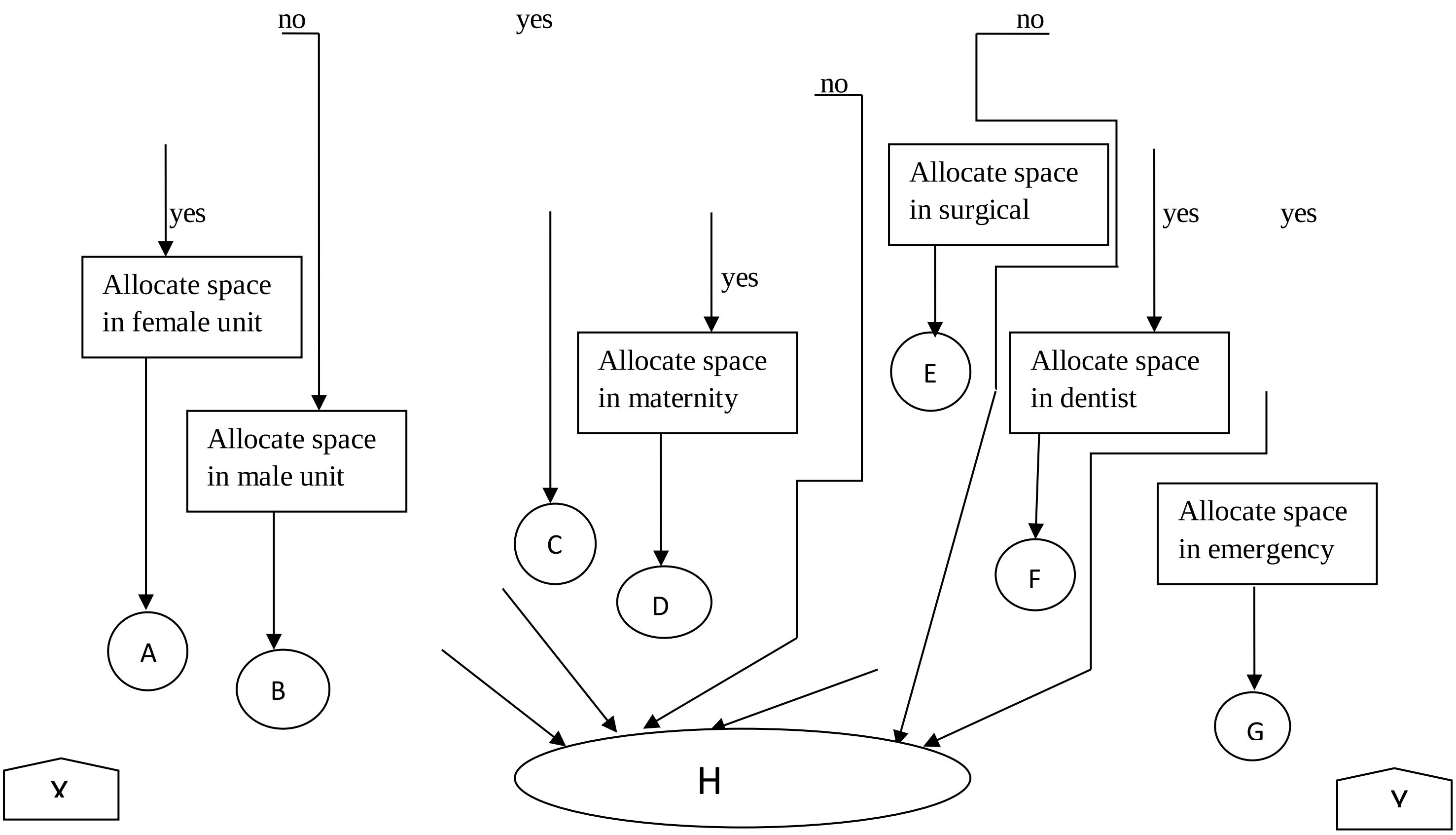
$$Q = Q - 1 \quad \text{where } Q > 0 \qquad \ldots 3.12$$

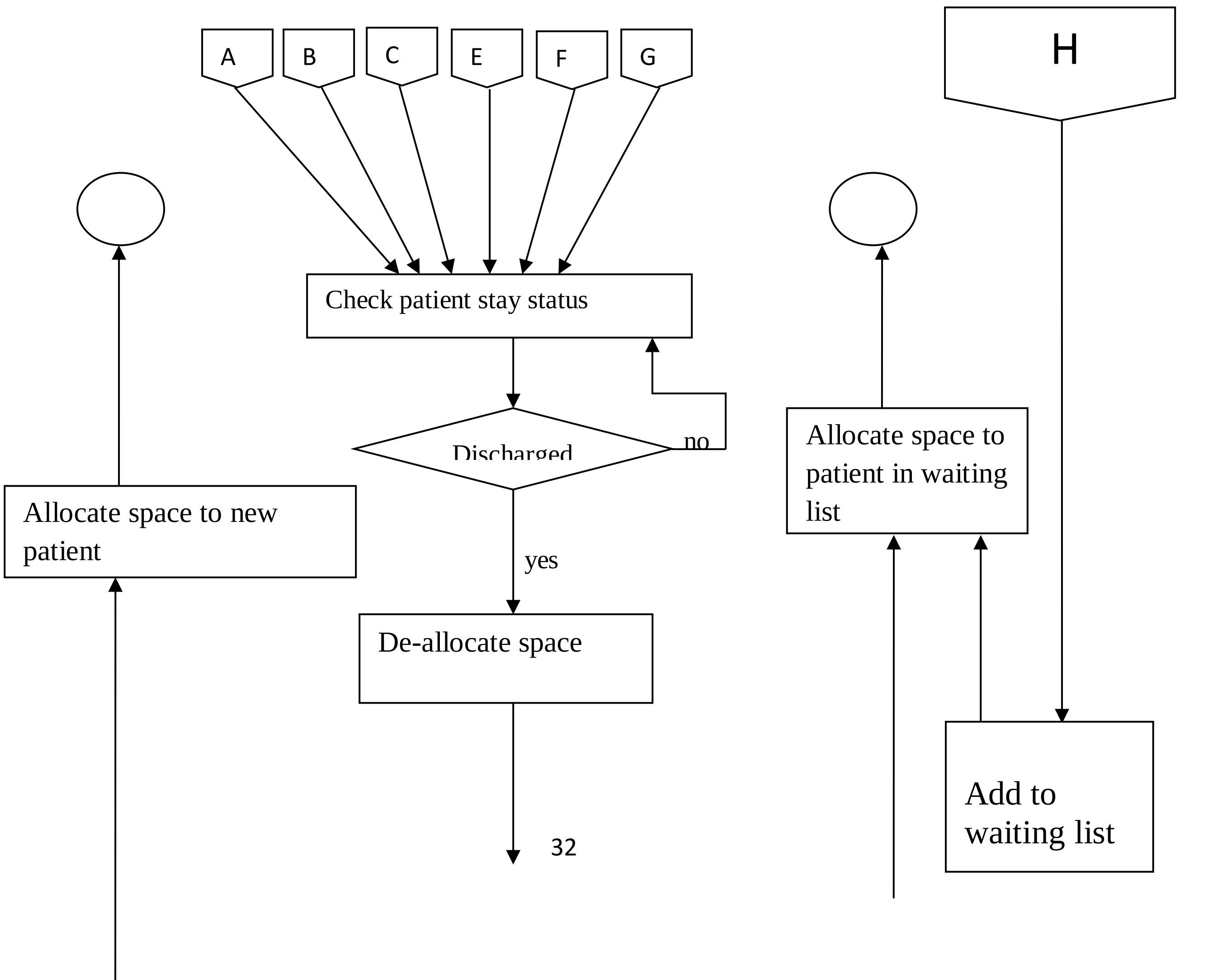
$$\beta = \beta + 1 \qquad \ldots 3.13$$

$$\lambda = \lambda - 1 \qquad \ldots 3.14$$

3.2.4 APPLICATION FLOW CHART




no
yes
no
no
yes
Allocate space in surgical
yes
yes
yes
Allocate space in female unit
yes
Allocate space in maternity
E
Allocate space in dentist
Allocate space in male unit
C
D
F
Allocate space in emergency
A
B
G
X
H
Y


A
B
C
E
F
G
H
Check patient stay status
Discharged
no
Allocate space to new patient
Allocate space to patient in waiting list
yes
De-allocate space
Add to waiting list

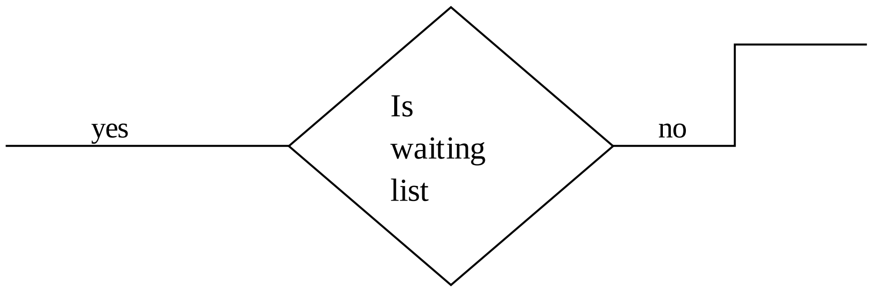


Figure 3.4: The Application Flowchart

3.2.5 DATABASE SCHEMA

The Database schema consists of four tables namely: Allocation table, Waiting-list table, Space-status table and Patient-register table. The Allocation table stores free bed space available, it stores the card number, allocated unit and bed number of the patient. Waiting-list table stores the patients that are yet to be allocated a bed space; it stores the card number, patient name, health category, arrival time and date of the patient. Patient-register table stores new patient that just arrived for admission, it stores the card number, patient name, stay status and health category. Space-status table stores the stay status whether discharged or not, it stores the units, number of free space and number of occupied space of the patient. The diagram below shows Table structure and Table schema of State Specialist Hospital, Akure Bed Allocation Database.

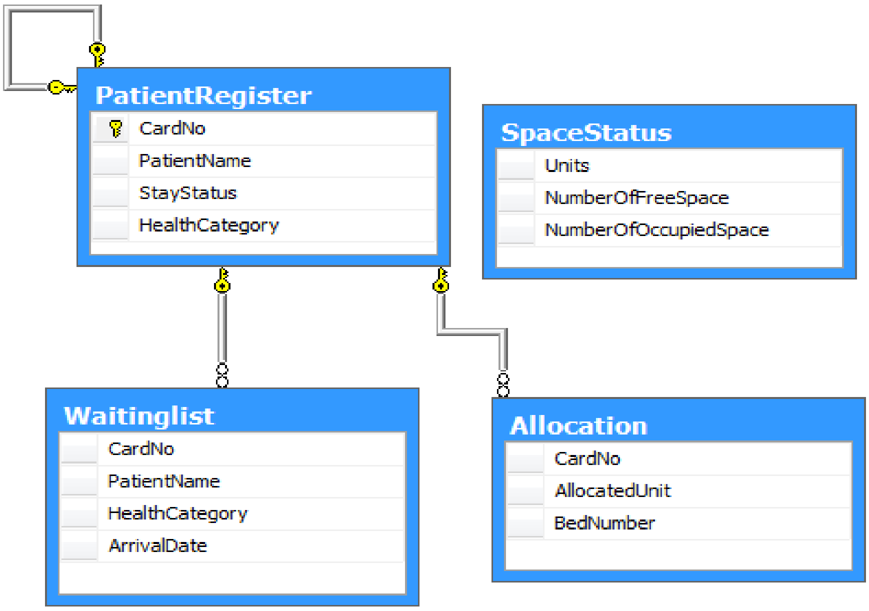


Figure 3.5a: Table Structure of the Database

Column Name	Data Type	Allow Nulls
CardNo	nvarchar(50)	☑
AllocatedUnit	nvarchar(50)	☑
BedNumber	nvarchar(50)	☑
		☐

Figure 3.5b: Table Schema for the Allocation table

Column Name	Data Type	Allow Nulls
CardNo	nvarchar(50)	☐
PatientName	nvarchar(50)	☑
StayStatus	nvarchar(50)	☑
HealthCategory	nvarchar(50)	☑

Figure 3.5c: Table Schema for the Patient-register table

Column Name	Data Type	Allow Nulls
CardNo	nvarchar(50)	☑
PatientName	nvarchar(50)	☑
HealthCategory	nvarchar(50)	☑
ArrivalDate	nvarchar(50)	☑

Figure 3.5d: Table Schema for the Waiting-list table

Column Name	Data Type	Allow Nulls
Units	nvarchar(50)	☑
NumberOfFreeSpace	nvarchar(50)	☑
NumberOfOccupiedSp...	nvarchar(50)	☑

Figure 3.5e: Table Schema for the Space-status table

CHAPTER FOUR

SYSTEM IMPLEMENTATION

4.0 INTRODUCTION

The purpose of the implementation phase is to translate the software design into source code. Each component of the design is implemented as a program module. The end-product of this phase is a set of program module that has been individually tested. During this phase, each module is unit tested to determine the correct working of all the individual modules. It involved testing each module in isolation as this is the most efficient way to debug the error identified at this stage.

During this phase, the software design of this project work on depicted in form of diagram and model chapter three is converted into tangible software by coding all program code implemented using C#(pronounced' C-sharp') programming language a Microsoft oriented language. System component shown in the system architecture in chapter three earlier are implemented one after the other in an object oriented fashion until all component are implemented. Other tools employed during the implementation phase include;

i. Microsoft Visual studio 2010 – Integrated Development Environment

ii. Microsoft SQL Server 2005 – Database Management System

iii. Asp.net – an HTML .net tag for designing user interface

4.1 SYSTEM TESTING

After the system had been completed and all components unit testing done with, the different modules or components are integrated in a planned manner. The integration was carried out incrementally over a number of steps. During each integration step, the partially integrated system is tested and a set of previously tested module are added to it. Finally, when all the modules have been successfully integrated and tested complete system testing was carried out. The system testing helped ensured requirement and design conformance. The kind of system testing carried out is α-testing (i.e. testing performed by the development team).

4.2 SYSTEM DOCUMENTATION

The documentation phase is another important phase in software development, as it provide platform for the successful implementation of subsequent phases such as software

Maintenance and Development. The software documentation is usually carried out as the tail end of the implementation phase. This phase involves the creation of installation manuals, technical documents, and user manual documents. The technical manual is a document that describes the technical detail or concepts of the software. Such document facilitates subsequent maintenance efforts and thereby cut maintenance cost. Other document produce include the user manual and installation requirement. These documents also facilitate system usability on the side of the user. The user manual is describe later, no provision had however, been made for the technical manual other than those describe in chapter three. The rational behind this is that this software is not full blown software but used only for the purpose of demonstrating the concept discuss in this project work.

4.3 SYSTEM REQUIRMENT

The following are the minimum system requirements to run the application;

i. Microsoft XP(SP2)/Vista Operating System/Window 7/Window 8

ii. 512MB of RAM or higher

iii. 40GB of HARD Disk space or higher

iv. Microsoft .NET framework 3.5 or later versions

v. Pentium IV or higher/ dual core processors

vi. Uninterrupted Power Supply Unit

vii. Stabilizer

viii. Printer LaserJet./ Desk

4.4 USER MANUAL

The following section provides a user manual in a page-oriented approach. That is some tasks or transactions are identified and a series of steps detailing how to accomplish them are explained.

4.4.1 HOME PAGE

The home page is the first interface encountered by the system user. It is an easy-to-use interface from within which other pages could be reached. The system user enters the username and password, and at the click of "Enter" it goes to the registration page. The home page is shown in the figure below;

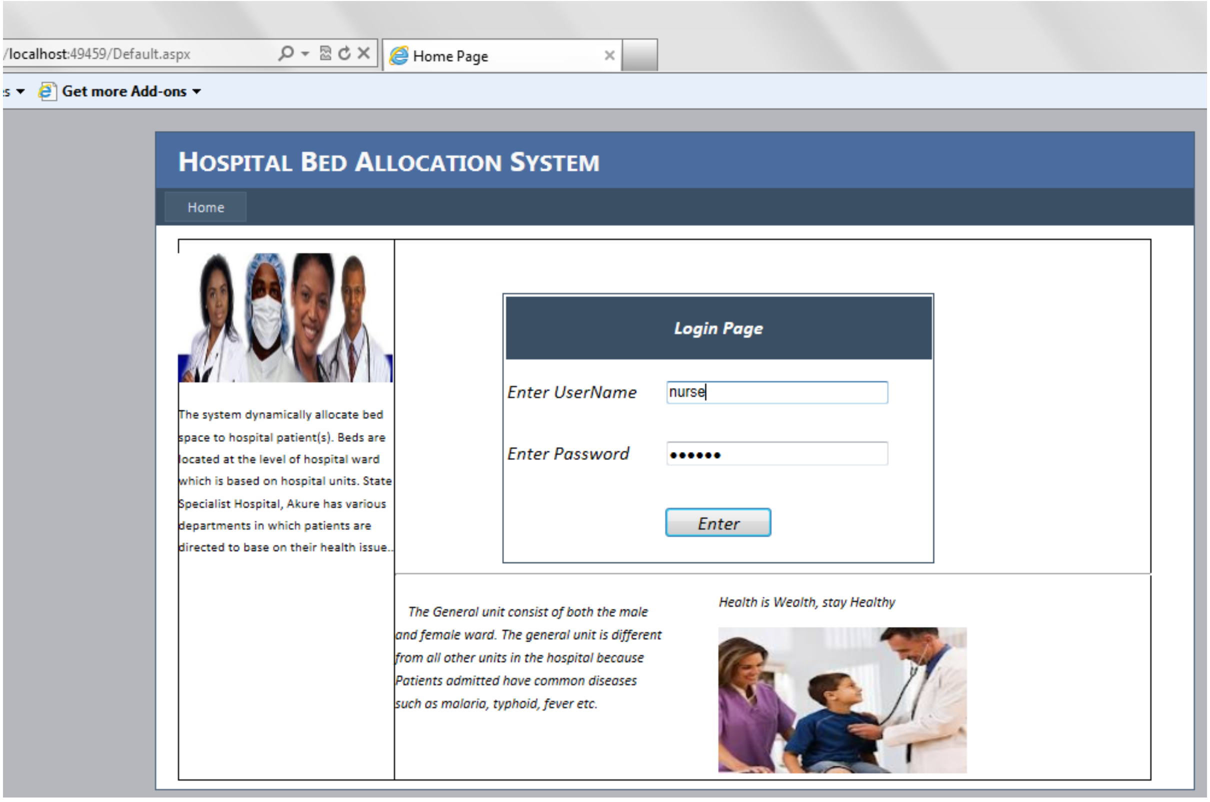


Figure 4.1: Home Page

4.4.2 REGISTRATION PAGE

The system user registers a new patient that is needed to be admitted including the patient medical details. Detail such as Card number, Full name, Name of next-of-kin, Health category, Patient address and Phone number. At the click of "enter", it assigns a bed space to the patient using the Health category to the appropriate ward. The registration page, make use of the bed allocation model discussed in previous chapter to allocate bed space for patient. The system checks for available bed space before allocating: if there are no free bed spaces it automatically assigns the patient to the waiting list. The registration page is shown below:

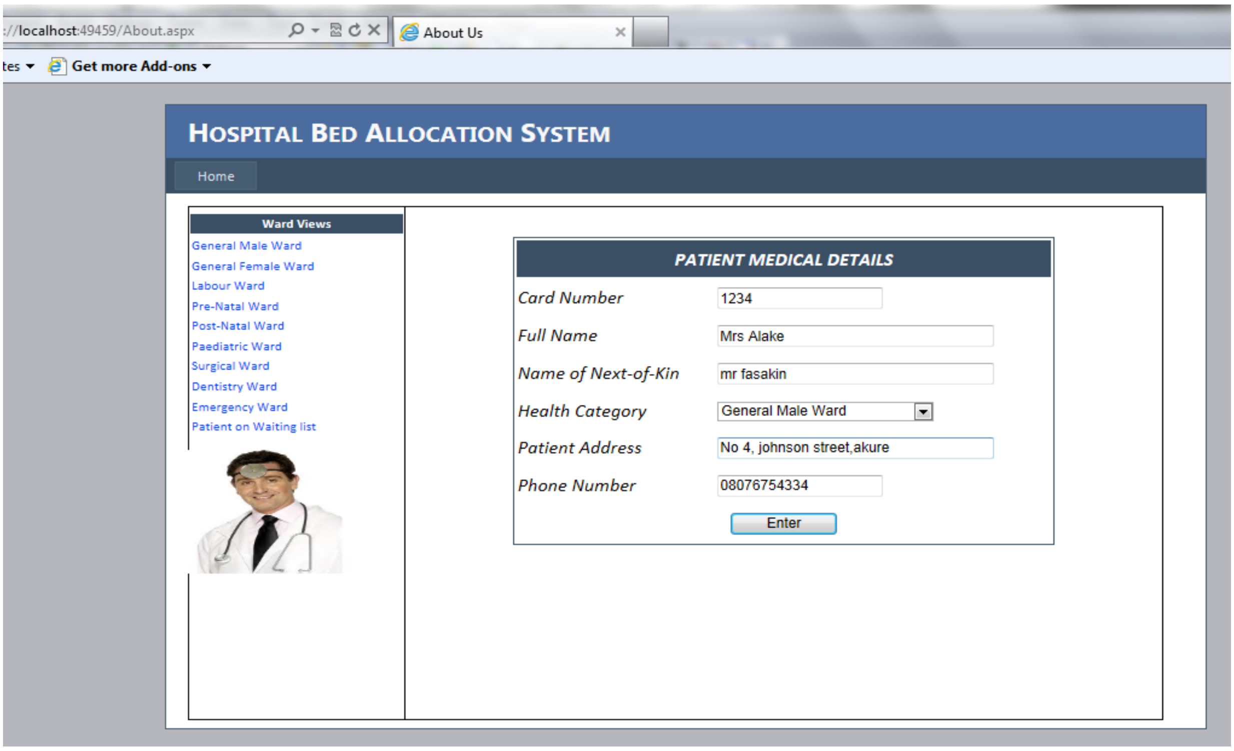


Figure 4.2: Registration Page

4.4.3 GENERAL MALE WARD PAGE

This page consists of number of beds available and occupied in the male ward. This page also allows the system user to view if there is a free bed space before registering any patient. It enables the system user to perform task such as discharge a male patient and view the patient's details. Male Patient with sicknesses such as malaria, typhoid and fever belongs to this ward. There are fifteen beds in this ward. The general male ward page is shown below:

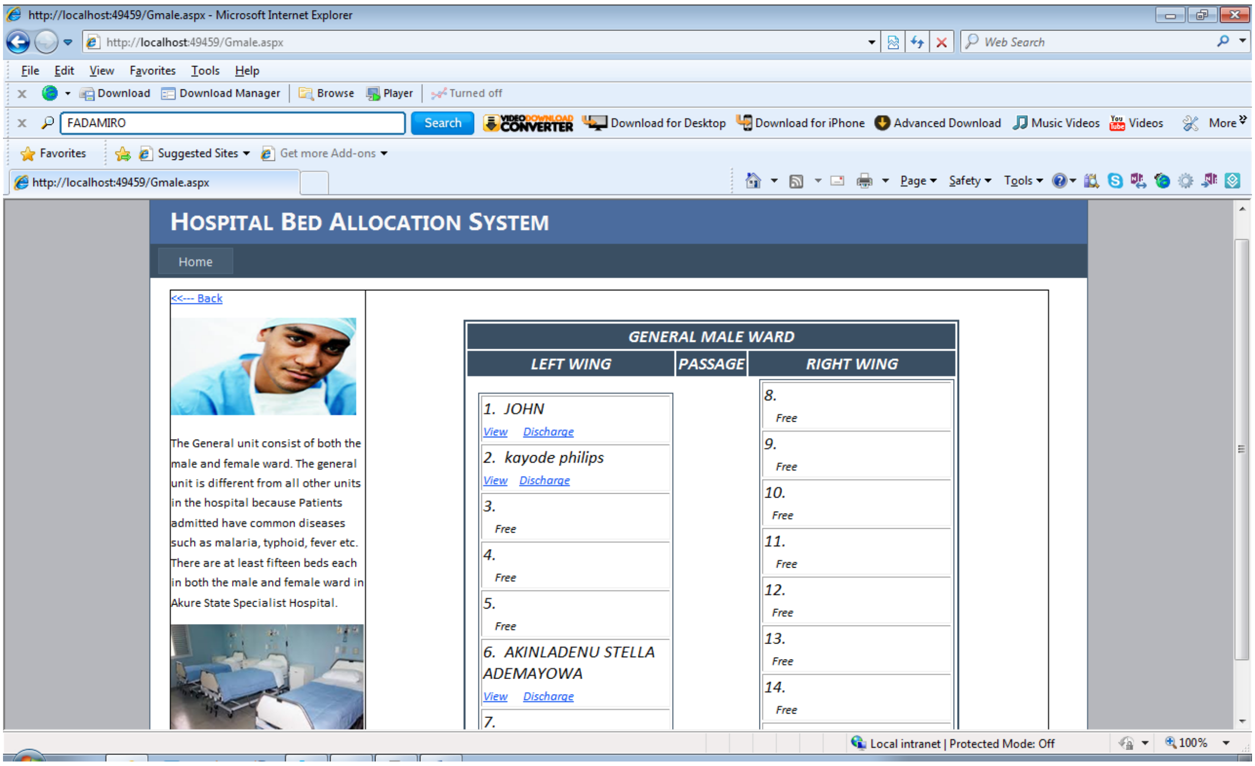


Figure 4.3: General Male Ward Page

4.4.4 GENERAL FEMALE WARD PAGE

This page consists of number of beds available and occupied in the female ward. This page also allows the system user to view if there is a free bed space before registering any patient. It enables the system user to perform task such as discharge a female patient and view the patient's details. Female Patient with sicknesses such as malaria, typhoid and fever belongs to this ward. There are fifteen beds in this ward. The general female ward page is shown below:

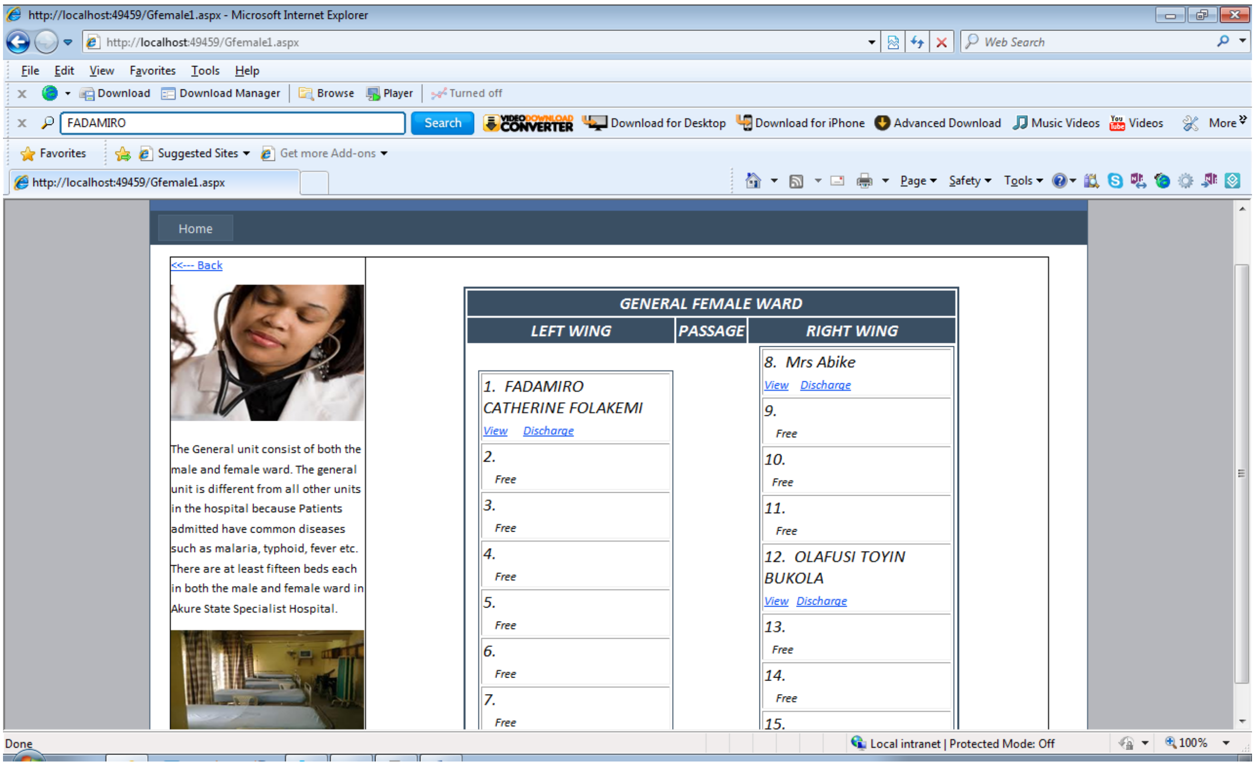


Figure 4.4: General Female Ward Page

4.4.5 PAEDIATRIC WARD PAGE (CHILDREN)

This page consists of number of beds available and occupied in the paediatric ward. This page also allows the system user to view if there is a free bed space before registering any patient. It enables the system user to perform task such as discharge a patient and view the patient's details. The Paediatric unit admits only children and is equipped with instruments and machines that are suitable for the small size. There are ten beds in this ward. The paediatric ward page is shown below:

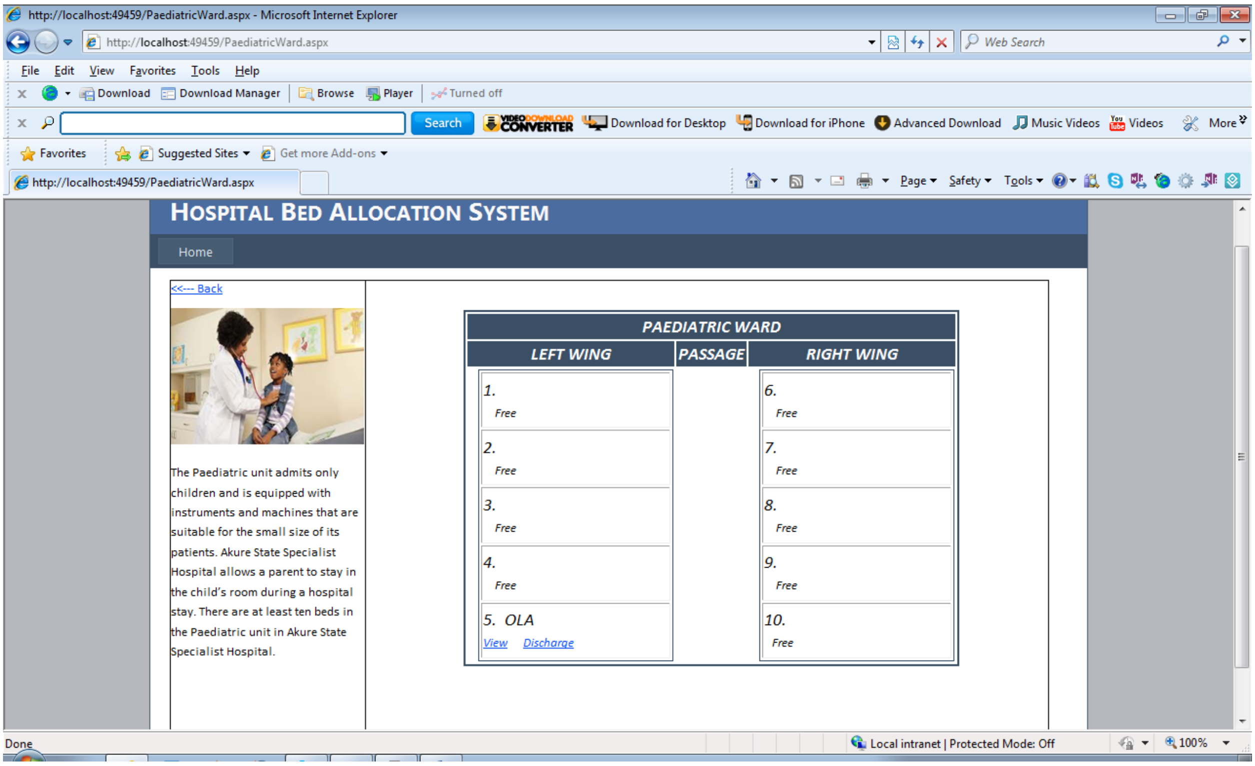


Figure 4.5: Paediatric Ward Page

4.4.6 SURGICAL WARD PAGE

This page consists of number of beds available and occupied in the surgical ward. This page also allows the system user to view if there is a free bed space before registering any patient. It enables the system user to perform task such as discharge a patient and view the patient's details. The Surgical ward is the actual operating room where a patient with a particular disease is being operated. There are ten beds in this ward. The surgical ward page is shown below:

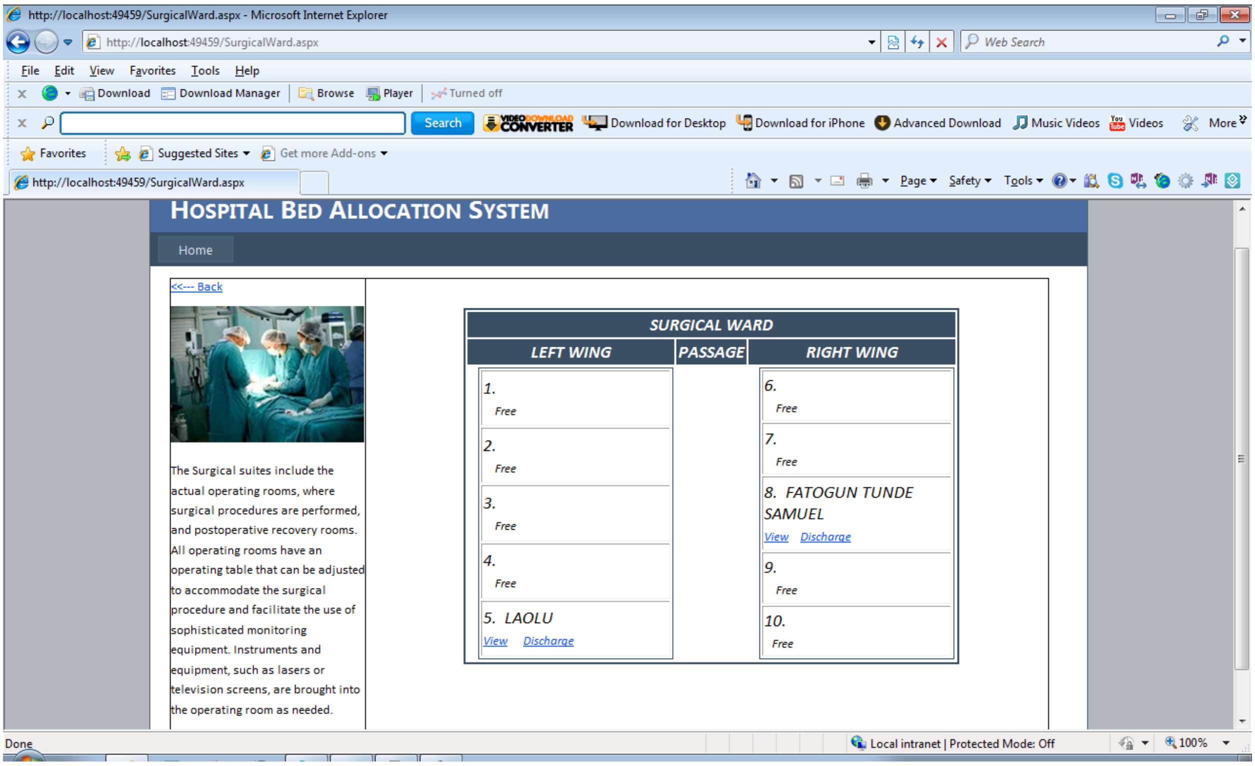


Figure 4.6: Surgical Ward Page

4.4.7 DENTISTRY WARD PAGE

This page consists of number of beds available and occupied in the dentistry ward. This page also allows the system user to view if there is a free bed space before registering any patient. It enables the system user to perform task such as discharge a patient and view the patient’s details. A Patient with oral cavity diseases belongs to this ward. There are five beds in this ward. The dentistry ward page is shown below:

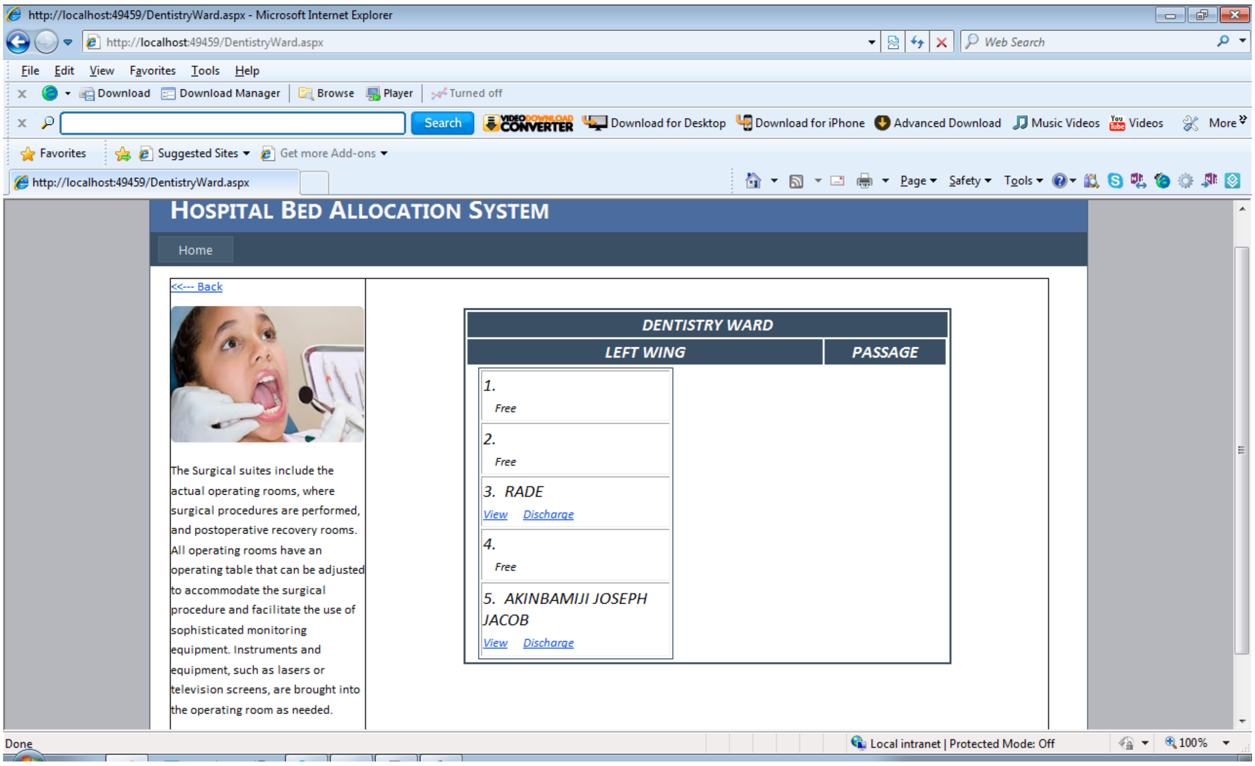


Figure 4.7: Dentistry Ward Page

4.4.8 PRE-NATAL WARD PAGE

This page consists of number of beds available and occupied in the pre-natal ward. This page also allows the system user to view if there is a free bed space before registering any patient. It enables the system user to perform task such as discharge a patient and view the patient's details. A Patient that is yet to give birth to a baby belongs to this ward. There are six beds in this ward. The Pre-natal ward page is shown below:

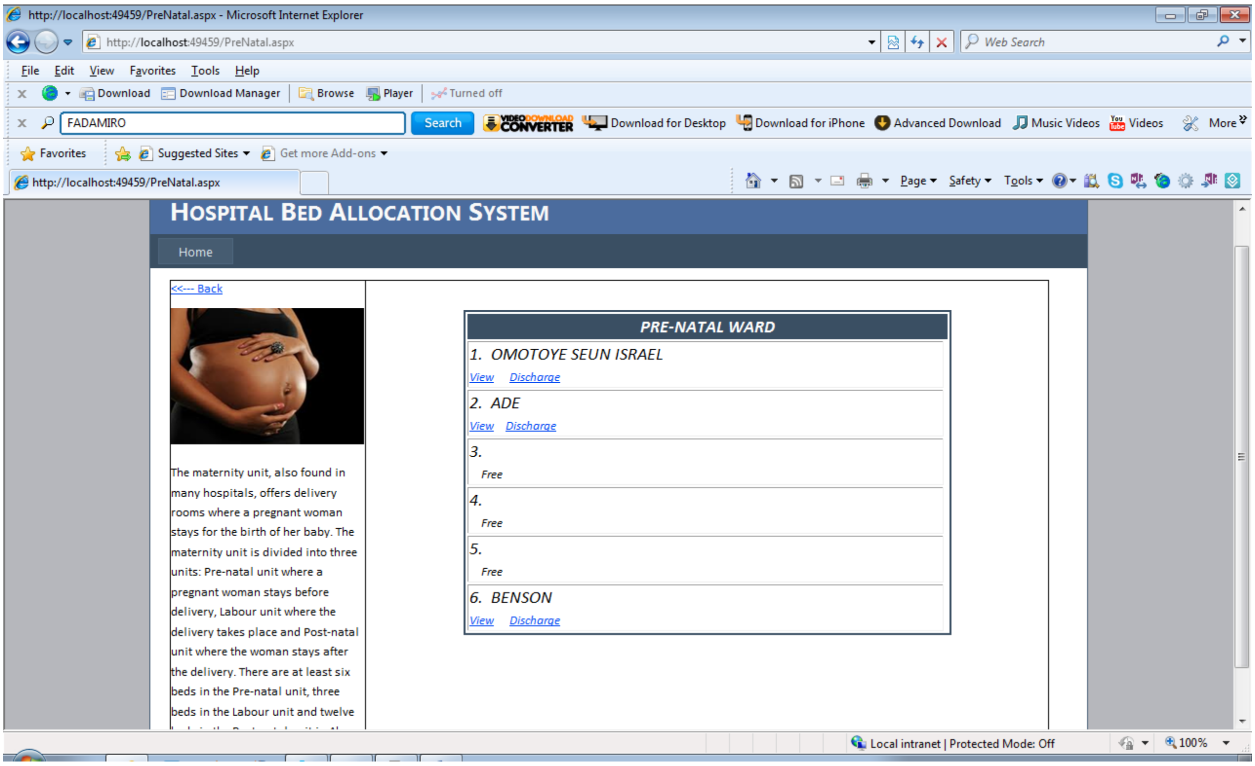


Figure 4.8: Prenatal Ward Page

4.4.9 LABOUR WARD PAGE

This page consists of number of beds available and occupied in the Labour ward. This page also allows the system user to view if there is a free bed space before registering any patient. It enables the system user to perform task such as discharge a patient and view the patient's details. A Patient that is ready to give birth to a baby belongs to this ward. There are three beds in this ward. The Labour ward page is shown below:

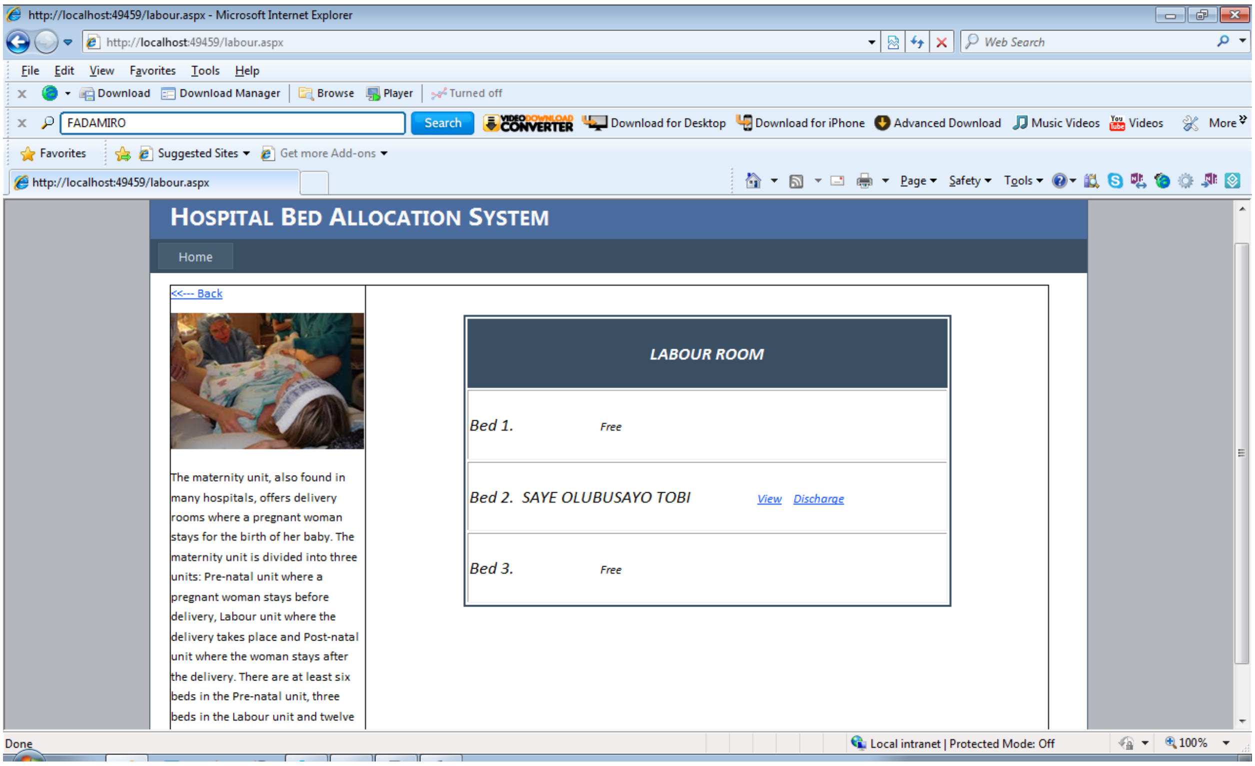


Figure 4.9: Labour Ward Page

4.4.10 POST-NATAL WARD PAGE

This page consists of number of beds available and occupied in the post-natal ward. This page also allows the system user to view if there is a free bed space before registering any patient. It enables the system user to perform task such as discharge a patient and view the patient's details. A Patient that just gave birth to a baby belongs to this ward. There are twelve beds in this ward. The Post-natal ward page is shown below:

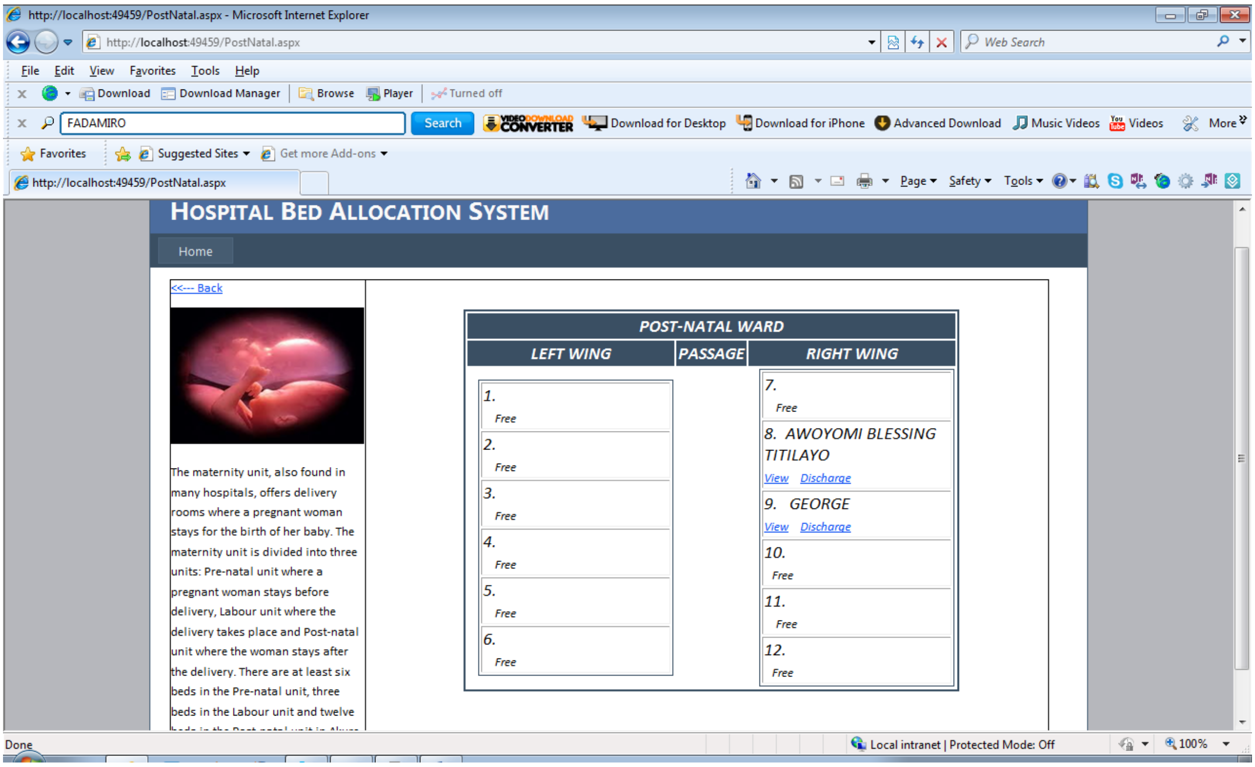


Figure 4.10: Post-natal Ward Page

4.4.11 ACCIDENT AND EMERGENCY WARD PAGE

This page consists of number of beds available and occupied in the Accident and Emergency ward. This page also allows the system user to view if there is a free bed space before registering any patient. It enables the system user to perform task such as discharge a patient and view the patient's details. A patient that is injured by an accident and any emergency case belong to this ward. There are fifteen beds in this ward. The Accident and Emergency ward page is shown below:

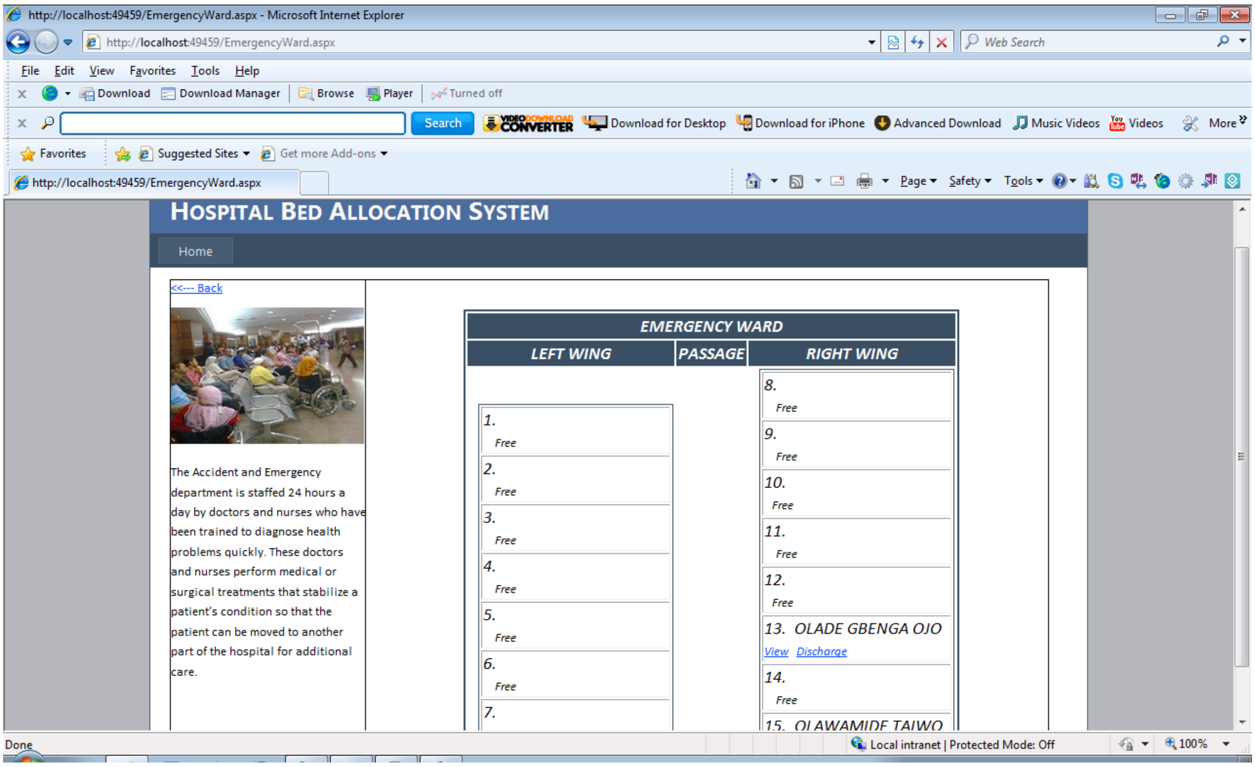


Figure 4.11: Accident and Emergency Ward Page

4.4.12 PATIENT WAITING LIST PAGE

This page stores the patients that are yet to be allocated a bed space. The system determines this at the registration page. It does this by checking for free bed space: and if there no free space, the patient is directed to the waiting list. On clicking the "MOVE" link, a particular patient is allocated a bed space immediately if there is, and that patient is removed from the waiting list, otherwise it is return back to the waiting list. The waiting list page is shown below:

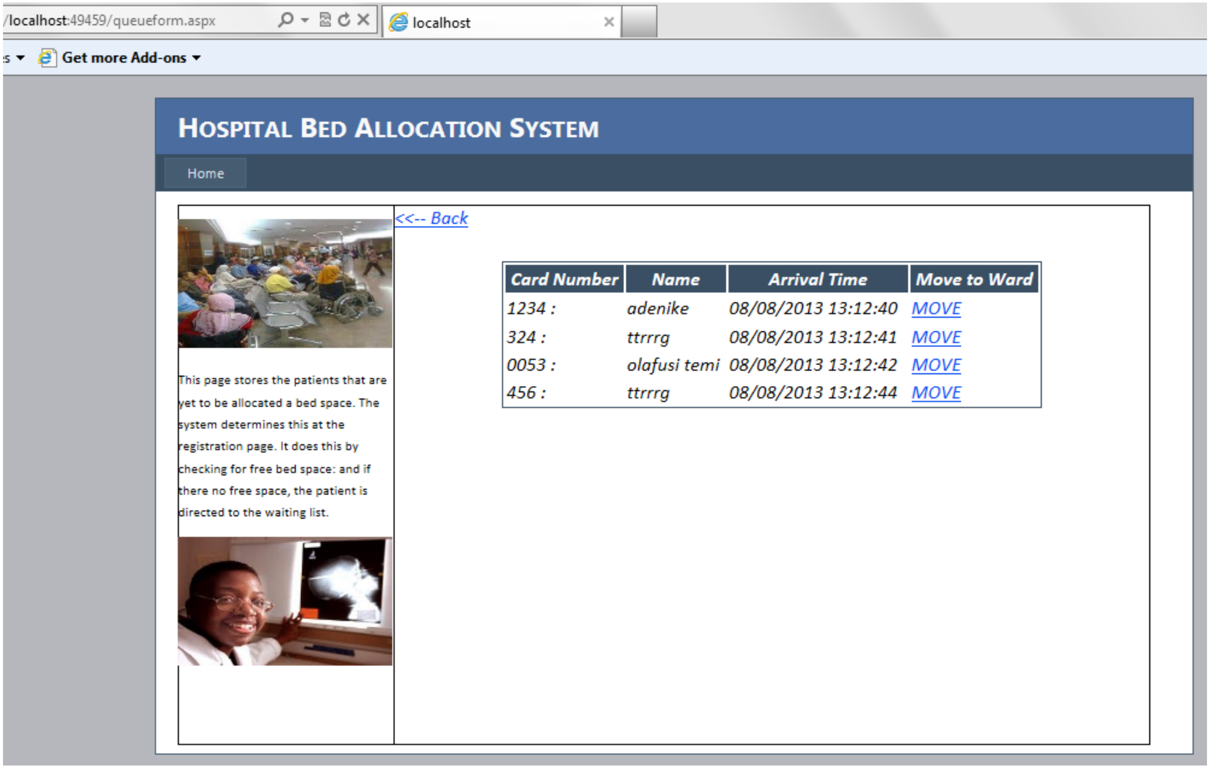


Figure 4.12: Patient waiting list Page

REFERENCES

Arun Kumar and John Mo (2010), “Models for Bed Occupancy Management of a Hospital” School of Aerospace, Mechanical and Manufacturing Engineering RMIT University, Melbourne, Victoria 3000, Australia.

Chris Hart, John Kauffman, David Sussman, and Chris Ullman (2006), “Beginning ASP.NET with C#”, Wiley Publishing, Inc.

Dr. Roger Henderson (2013), http://NetDoctor.co.uk.

Guoxuan Ma and Erik Demeulemeester (2010), “Assessing the performance of hospital capacity planning through simulation analysis” Department of Decision Sciences and Information Management.

Jagran Josh (2011), “career in Hospital Management” MMI Online Limited.

Ling Gao, Liang Lin, Lianlong Gao (2010), “Uncertain Models for Bed Allocation” Guangxi national Science Foundation of China (Gui No. 0832261).

Lippincott Williams and Wilkins (2006), Stedman’s Medical Dictionary 28th Edition.

Matthew MacDonald (2007), “Beginning ASP.NET 3.5 in C# 2008: From Novice to Professional”, Second Edition netbooks.wordpress.com.

Ministry of Health and Long-Term Care (2010), “Hospital Emergency Departments” Annual Report of the Office of the Auditor General of Ontario.

Net Resource International (2012), “hospital management.net” Cornhill Publications Limited.

Nicholls, Angela G. and Young, Frank R. (2007), "Innovative hospital bed management using spatial technology” Spatial Science Queensland, pp. 26-30, ISSN 1032- 3848.

Richardson, Drew B. (2003), “Reducing patient in the emergency department” The Medical Journal of Australia, 170 (10), p.516-517.

Seung-Chul Kim, Ira Horowitz, Karl K. Young and Thomas A. Buckley (2000), “Flexible bed allocation and performance in the intensive care unit” Journal of Operations Management.

Shu-Ching Chen , Sneh Gulati , Shahid Hamid , Xin Huang , Lin Luo , Nirva Morisseau-Leroy , Mark D. Powell , Chengjun Zhan and Chengcui Zhang (2010), “A Three-Tier System Architecture Design and Development for Hurricane Occurrence Simulation” School of Computer Science, Florida International University, Miami, FL 33199, USA.

Sikha S.B, Richard W.E (2006), “Learning SQL on SQL Server 2005”, O’Reilly Media.

Sophie D. Lapierre , David Goldsman, Roger Cochran and Janice DuBow (1999), “Socio-Economic Planning Sciences” Elsevier Science Ltd.

Sreenath G V, Sastha Krishnan V, Sarah Mathew and Kailas Sree Chandran (2010), “Operating Room Allocation Using Mixed Integer Linear Programming (MILP)” Department Of Mechanical Engineering College Of Engineering Thiruvananthapuram.

Ward, Dr Michael (2004), “Bed Management Collaborative” Queensland Health Quality and Safety Improvement Program, Queensland.

Wikipedia, The Free Dictionary, http://en.wikipedia.org/The free dictionary, Retrieved on May 2, 2013.