Analysis of IV-pump Management Alternatives Using Simulation

by

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AUTHOR'S DECLARATION FOR ELECTRONIC SUBMISSION OF A THESIS

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

The objective of this thesis was to better understand the patterns of IV-pump use throughout the hospital in order to provide guidance to the hospital on alternative pump management methods. In the current system, when the number of available pumps in a department was fewer than the number of pumps required for patient care, the department encountered shortage. In most cases, the personnel were not clear on where available pumps might be stored and had to search for free pumps throughout the hospital.

The system was thoroughly studied and the necessary data were collected. A model reflecting the current flow of patients and pumps was developed. This model was operationalized by constructing a simulation model. The model presented the flow through the hospital on a daily basis.

The output of the simulation model provided the daily number of pumps in use in each of the departments and the distribution of pump use for each department, separately, and overall. Using these distributions, the number of pumps required in each department if maintaining a supply of pumps was quantified to meet certain service levels. In addition, the number of pumps required in the system if the pumps were all shared, was also obtained. It was concluded that the actual number of pumps required in the system is fewer than the number of pumps existing in the hospital. This conclusion confirmed that long searches for free pumps were not due to insufficient quantity of pumps, but were solely due to the behaviour of hoarding extra pumps when available. The simulation also provided the number of pumps short per day and the number of pumps in excess per day, by department.

Two pump management alternatives were suggested to the hospital. The first alternative was to utilize a centralized pool to keep all shared pumps when not in use. The second alternative was to install RFID technology throughout the hospital and equip all pumps with RFID tags so that they could be easily located. The three pump management systems (current, central pooling, and RFID) were compared, and the advantages and disadvantages of each of the alternative techniques were discussed.

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Chapter 1: Introduction

Health Care is the largest industry in Canada. In 2001, the total spending was over $106 billion ($3,416 per person), or close to 10% of the Gross Domestic Product (GDP). With the population aging and the costs of drugs and technologies increasing, the Canadian health care system is in the midst of a serious financial crisis. However, by using Operations Research (OR) techniques, which help planning, coordinating, controlling and evaluating the use and allocation of health care resources, the industry can be run a lot more efficiently (Carter, 2004).

Although the benefits of applying OR techniques in health care industry are becoming more and more evident, a number of constraints still exist in this regard. In an interview with the Medical Post (Bushe, 2004), Carter declared, "There's an attitude that spending money to improve systems only diverts funds from patient care. In fact, putting money into analysing and optimizing the way we operate our hospitals will greatly benefit patients." An important problem with health care as indicated by Carter (2006) is the tendency for individual departments or services to operate as isolated segments and optimize their own processes without considering the larger systems issues. He continues that with modeling tools it is possible to understand very complex systems in health care and make rational decisions. Following are a number of examples of OR applications in health care (Carter, 2002):

- Simulation: is used for analyzing complex queuing problems. It can deal with the issue of waiting times and can help visualizing the impact of local decisions on the whole system.
- Linear Programming and Goal Programming: is used in a number of applications including staff scheduling, budget allocation and case mix management, among others.

- Data Envelopment Analysis (DEA): is a management tool that is commonly used to evaluate the efficiency of a number of producers (decision making units) (DEA, 1996). Several DEA papers were published in the health care sectors.
- Integer Programming: is used for facility location and staff (nurse and physician) scheduling problems, e.g. locating emergency medical services and ambulance location. Linear and mixed integer models have been developed to improve patient treatment, e.g. the optimization of radiation beams that travel through the body to treat cancer patients.
- AIDS Epidemic Modeling: much of OR modeling in AIDS research is systems dynamics models. Mathematical modeling has had an effect on AIDS policy in a number of areas, including estimating HIV prevalence and incidence, understanding the pathophysiology of HIV, evaluating costs and benefits of HIV-screening programs, evaluating the effects of needle-exchange programs, and determining policies for HIV/AIDS care.
- Queuing Models: are developed for managing hospital waiting lists and allocating beds in a hospital to various services.
- Quality Management: In North America in the early to mid-1990s, hospitals were just beginning to do quality assurance using tools like statistical process control to monitor (immediate) outcomes.

Asset management in health care is an area with high potential for applying OR techniques in order to improve the quality of patient care and control costs. It facilitates efficient use of assets using appropriate inventory control and reduces costs associated with locating the essential equipment. The high cost of medical equipment and complex flows through hospitals increase the need for effective equipment management techniques. In this regard, questions that frequently arise are: Do we have enough equipment? How do we manage inventories? Should they be allocated per department or are they better managed in one or two centralized pools? Can technology such as RFID provide operational benefits for asset management?

This thesis studies such questions for IV-pump management for the Grand River Hospital in Kitchener, Ontario. A simulation model is developed to gain a better understanding of current operating practices within the hospital. It captures patient flow and IV-pump requirements in all major departments so that we can assess whether there are sufficient pumps available, and to compare various strategies for allocating the inventory of pumps.

As a result of developing the simulation model, the number of IV-pumps required to ensure a specified service level for each department and the hospital as a whole is determined. This differentiates this research from earlier studies. The inventory of medical equipment required in a system has not been quantified before. This research proves that IV-pump shortages in the hospital are not due to insufficient inventory of IV-pumps, but are due to behavioural issues that can be studied thoroughly in future research. The costs of daily shortages of IV-pumps resulting from two recommended asset management strategies are also quantified so that they can be compared against the cost of shortages of IV-pumps in the current system. Advantages and disadvantages of several asset management methods are discussed. In summary, this thesis demonstrates the value of quantitative methods to asset management in the health care sector.

1.1 Background Information

This section presents a general overview of the work done for this thesis and describes a number of terminologies that are used in this thesis.

Two terms are commonly used for patients in a hospital, “inpatient” and “outpatient.” The patients whose treatment takes less than a day and do not stay in a hospital overnight are called outpatients. Patients who are kept in a hospital at least for one night are called inpatients. This study focuses on the latter category.

Medication is taken by patients in different ways. A large portion of the patients receive their medication through infusion pumps. According to Hoffman (2002), an infusion pump is a device that is used to deliver very small quantities of drugs over long periods of time. This study focuses on IV-pump management. An IV-pump is a type of infusion pump. IV stands for intravenous that means into a vein. Therefore, an IV-pump gradually delivers a drug or fluids into a patient's vein. When the intravenous therapy is controlled by a nurse without using an IV-pump, it is called a 'manual drip.'

In this thesis: The term "pump" is used as a substitute for the term "IV-pump" from this point forward; all cost figures are in Canadian Dollars; and "fiscal year" is the period starting from April of each year until March of the year after.

This study is based on actual data from the Grand River Hospital in Kitchener, Ontario. The data includes the number of patients admitted into the hospital, their movements between departments, and the number of patients released from the hospital for a period of 121 days. Six major departments that face shortages of pumps are taken into account. Patient flow probability distributions that are fitted to the actual data are acquired using version 6.00 of ExpertFit. ExpertFit is a probability distribution fitting software, designed by Averill M. Law and Associates (Law, 2006). Patients' pump requirement distributions are obtained through hospital experts' responses to questionnaires designed for this purpose. A simulation model is developed using version 2005 of Simul8, which is a simulation software originally introduced in 1994 by Simul8 corporation (Simul8, 2006). The results are collected from running the simulation model for 10 periods of 365 days (one year). Output is analyzed and alternative pump management methods are assessed.

1.2 Problem Statement

In a hospital environment, prompt access to clinical equipment is critical. One such piece of clinical equipment is an infusion pump that infuses medication and nutrients into a patient's circulatory system. Infusion pumps are used for a considerable number of patients in a hospital.

At the Grand River Hospital (GRH), a large number of infusion pumps are shared by departments across the entire hospital. While most departments do not ‘own’ a quota of pumps, a few of the departments maintain a stock of pumps due to their constant need and the inconvenience of having to obtain additional pumps. This will be discussed later in the study.

In the current system, when a patient enters the hospital, he or she is moved to one of the beds in the appropriate department. If this patient is in need of one or more pumps, staff can either use a pump that has been released by another patient in the department, or they will need to acquire a pump from another location in the hospital.

In general, when a pump is removed from a patient and is not immediately needed for another patient in that department, it is made available for use by other departments. The current practice in the hospital is to leave unused pumps in the department that last used them, and if a different department needs a pump, the staff from that department will need to first locate it and then to pick it up. This process is not only frustrating, but also time consuming. The staff member who is sent to look for a free pump, is most of the times from housekeeping or clerical staff, however, sometimes nursing staff search for a pump. This process results in a waste of staff’s valuable time, an extra cost for the hospital, and a deficiency in service quality. In fact, some departments tend to hoard extra pumps in prediction of future needs. Their reason behind this action is that when they need a pump, they have to go through the time and energy consuming process of calling other departments, getting negative responses, and then physically having to search for available pumps.

The Emergency department suffers the most from this problem. In this study, Emergency acts as an admission point for other departments in the hospital. The majority of patients admitted through Emergency are first connected to a pump, and then transferred elsewhere in the hospital. Since the pumps are not automatically returned to Emergency, this department ends up searching for pumps every day. While patients staying in other departments are usually disconnected from a pump before being transferred to another department, this is not the case with the Emergency Department. It is easy to see that overall, there is a net flow of pumps out of this department.

In some occasions, in order to avoid the search process, the departments deal with their shortages by disconnecting a pump from an existing patient with less critical condition, whose drip can be managed manually, and then connecting the freed-up pump to the new patient. This procedure may be a solution to an immediate need, but it increases the work of the nurses who control the manual drip.

At first glance, it may seem that the total number of pumps in the hospital is not sufficient to cover demand; however, this research reveals that the number of pumps available is not the reason for long and frustrating searches, but the need for improved pump management is the root cause of this problem.

1.3 Objectives

The key objective of this study is to better understand the patterns of pump use throughout the hospital in order to provide guidance to the hospital on alternative pump management methods. To achieve this objective, a simulation model was developed. The model presented the flow of pumps through the hospital on a daily basis. The output of the simulation model provided distributions of total pumps needed by each department and the entire hospital per day.

In order to provide guidance to the hospital on pump management, the simulation can also be used to study the costs and benefits of various pump management strategies. The current system results in distributed inventories of pumps, where personnel are not clear on where available pumps might be stored. An alternative is to consider a centrally managed pool of pumps so that the hospital may take advantage of a pooled inventory. Another alternative that the hospital is considering is the use of an RFID system so that pumps, when not in use, can be more easily located. Advantages and disadvantages of all three pump management methods are discussed.

1.4 Thesis Organization

This thesis is composed of seven chapters and eleven appendices. Chapter 2 describes the Grand River Hospital and its services. Chapter 3 summarizes the literature related to this study. Chapter 4 explores the details of patient and pump flow in the current system. In addition, it explains the characteristics and fundamental assumptions of the simulation model. The design of production runs is described in Chapter 5. The results of the simulation runs are presented and analyzed in Chapter 6 and two alternative pump management strategies are thoroughly explored. In addition, advantages and disadvantages of all three pump management methods (current, central pooling, and RFID) are discussed. Finally, Chapter 7 summarizes the conclusions and outlines a number of suggestions for future research. Appendices A to K can be found after Chapter 7.

Chapter 2: Site Description

This chapter provides a description of the Grand River Hospital, the departments in the studied system, services and patient care environment, history, and staff demographics. The information presented in this section was acquired and summarized from the official website of Grand River Hospital (Grand River Hospital, 2005).

2.1 Grand River Hospital

Grand River Hospital is a multi-site facility that provides acute, complex continuing and cancer care to more than 450,000 residents in the Region of Waterloo and the surrounding communities. Grand River Hospital (GRH) is comprised of three distinct facilities. They are as followings:

- Kitchener-Waterloo Health Centre (K-W Health Centre)
- Freeport Health Centre
- Grand River Regional Cancer Centre

All sites are located in Kitchener, Ontario. GRH offers the following programs and services:

- Childbirth and Children's Program
- Medical Program
- Surgical Services
- Oncology Program
- Complex Continuing Care Program
- Rehabilitation Care Program

- Emergency Services
- Administrative and Clinical Support Services
- Psychiatric and Mental Health Program
- Critical Care Services
- Renal Program

Grand River Hospital has 495 beds, 2500 professional staff and 800 volunteers. For the fiscal year 2004/2005, total admissions for inpatients were 14,121. The Emergency department saw 50,745 cases, most of which were admissions for outpatients.

2.2 Health Care Team

To provide quality patient care, GRH requires the collaboration of skilled and dedicated personnel. Upon arrival at Grand River Hospital, a multidisciplinary team will assess patients' needs and determine what services they require. Health care team may include clinical directors and medical directors, clinical medicine specialists, clinical resource nurses, clinical support staff, general practitioners and family physicians, diagnostic imaging staff, dieticians, the foundation team, laboratory staff, laboratory medicine specialists, non-clinical support staff, nursing staff, occupational therapists, pastoral care, pharmacists, physiotherapists, psychologists, recreation therapists, resource/charge nurses, respiratory therapists, social workers, speech language pathologists, students, surgical specialists, therapy assistants, and volunteers.

This study had the support of clinical directors, whose responsibilities include team leadership to the frontline health care team to ensure patients care through efficiency and accountability, and Non-Clinical Support Staff who provide a wide-range of services and support that includes clerical, maintenance, housekeeping, education, and administration.

2.3 History

Kitchener-Waterloo Hospital was first established in 1895 as the Berlin-Waterloo Hospital. Seventy patients were cared for in its first year. The 30-bed facility had one operating room, a handful of nurses, and a dozen physicians. The hospital's School of Nursing opened the following year and trained more than 1400 nurses before closing 80 years later.

Freeport Hospital first began as a tuberculosis sanatorium. Following medical advances and altered treatment of tuberculosis after World War II, Freeport began admitting chronic care and rehabilitation patients. It was the first facility in the province to initiate a move into this direction of care. During the 1960s, the need for chronic care beds continued to grow resulting in the addition of more beds, and by 1970 the Freeport Sanatorium became Freeport Hospital.

2.4 Departments

This section provides an overview of the departments of the Grand River Hospital that are selected for this study. In general, departments can be divided into two different categories: service departments and patient care departments.

2.4.1 Service Departments

Service departments are described as departments whose role is not directly associated with patient care. Three service departments that have a major role in pump flow are: Biomedical Engineering, Sterile Processing, and Retail Pharmacy.

2.4.1.1 Biomedical Engineering

The Biomedical Engineering department is responsible for diagnosis and maintenance of the electronic equipment, borrowing from outside organizations the required devices that are not available at GRH, and managing equipment assets. Biomedical Engineering consists of 4 staff members who are responsible for maintenance of 4047 electronic devices in the hospital.

2.4.1.2 Sterile Processing

The Sterile Processing department (SPD) processes all reusable medical devices used in both K-W and Freeport health centers. SPD processing includes, but is not limited to cleaning, disinfecting, inspecting, assembling, packaging, sterilizing and distribution of all reusable medical supplies and equipment. SPD also manages a complete quality assurance program for all of its processes, including biological testing of all sterilizers (steam, Steris and Sterrad), chemical indicator monitoring, and air removal testing and documentation of the sterilizers. Infusion pumps that are not cleaned in each of the departments for immediate use are sent to SPD for decontamination process. This process is done by using standard hospital disinfectants such as “Omega.” Sterile Processing department consists of 26 staff members.

2.4.1.3 Retail Pharmacy

Retail Pharmacy, with an extensive inventory of prescription and non-prescription medications, offers a variety of services including professional medication counseling and on-line ordering of prescription refills and home delivery. The pharmacy also has a home care department which offers state-of-the-art manufacturing equipment to its clients for preparing a full range of home intravenous medications including specialty infusion pumps for IV drugs.

2.4.2 Patient Care Departments

At Grand River Hospital, the following services are offered to the patients in the corresponding departments:

Cardiology, Childbirth Services, Children's Services, Complex Continuing Care, Dialysis, Emergency, Geriatric Care, Intensive Care, Medical Imaging, Palliative Care, Psychiatry/Mental Health, Rehabilitation, Special Testing, and Surgical Services.

Complete description of these departments and Grand River Regional Cancer Centre can be found in Appendix A. This section reviews departments that are directly studied in this thesis.

2.4.2.1 Cardiology department

The cardiac services provide care for patients with primary and secondary cardiac disease. These services are conducted in cardiac care unit (CCU). CCU consists of 9 beds, which are used for the admission, care, and treatment of patients in the critical stages of a cardiac event, such as a heart attack, heart failure, or life-threatening heart rhythm disorders. CCU is equipped with technological support, including close, continuous observation, and early detection and intervention.

2.4.2.2 Children's Services

The K-W Health Centre of Grand River Hospital provides level II paediatric and neonatal inpatient services along with specialized outpatient clinic services. The children's unit consists of 10 outpatient, and 37 inpatient beds. 19 beds are allocated to neonatal inpatients and 18 beds are for paediatric inpatients. This thesis focuses only on paediatric inpatients. The department is called "Paediatrics" throughout the report.

2.4.2.3 Inpatient Oncology

The Inpatient Oncology unit deals with the treatment of malignant tumours. The unit has 18 inpatient beds and is now a program of the Grand River Regional Cancer Centre (GRRCC). However, it is located on the 8th floor of the K-W Health Centre and lacks direct access to the GRRCC next door. Patients with a diagnosis of cancer who require acute care interventions are admitted to the acute pain and symptom management unit for investigation and symptom management. This unit has 6 beds and together with Inpatient Oncology is called “Oncology Department” throughout this report.

2.4.2.4 Intensive Care

Grand River Hospital's intensive care unit (ICU) provides care for adults and children with acute, life threatening medical conditions due to illness, injury, or elective intervention, in which one or more vital systems are impaired. ICU consists of 12 acute patient beds. The unit provides intensive nursing, invasive and non-invasive monitoring, respiratory support, dialysis and other therapeutic interventions designed to restore and maintain stability, leading to transfer to a less intense level of care at the earliest time possible.

2.4.2.5 Medical Program

The Medical Program provides care for inpatients with non surgical procedures. They also offer inpatient rehabilitation to medical patients whose needs can be met within seven to ten days. The program consists of four units on the 5^{th} floor of K-W Health Centre with a total of 86 beds.

2.4.2.6 Surgical Services

The Surgical Services program supports a diverse range of surgical procedures. The surgical team members including surgeons, nurses, and health care professionals work closely with all departments within the hospital to provide patients with optimum health care services. They provide a wide range of services, however, only the ones that are related to this study are discussed in this section.

- “Inpatient Surgery,” in other words, “General Surgery” provides care to all adult surgical patients, pre-and post-operatively. This section of Surgical Services is the department that is called “General Surgery” in this study and consists of 76 inpatient beds.
- Day Surgery provides same day admission for all surgical patients.
- Operating Rooms provide peri-operative care for all surgical patients. There are 7 Operating Rooms at the K-W Health Centre.
- Post-Anaesthetic Care Unit (PACU) provides post-anaesthetic care for all surgical patients, providing separate space for children with attending parents. PACU also provides post procedure care for diagnostic imaging procedures.

2.4.2.7 Emergency

Grand River Hospital operates the largest emergency department in the Waterloo Region. Their staff members provide paediatric and adult emergency care 24 hours a day, 7 days a week. The department has 38 beds. On average 150 patients visit Emergency department every day. About 80% of the patients are outpatients. The rest of the patients are sent to other departments according to their medical care requirements. In this study, the Emergency department is considered as the entry point for six other departments in the study; therefore, only 20% of the patients who are admitted into the hospital as inpatients are investigated.

2.5 Summary

This chapter provided useful information about the Grand River Hospital. The history and current situation of the hospital were discussed and departments that play a role in this study were explained. Appendix A consists of description of all patient care departments of the hospital. Complete information about the hospital and its services can be found in the official website of the Grand River Hospital (Grand River Hospital, 2005), which was the source of the material presented in this chapter.

Chapter 3: Literature Review

In this chapter, studies previously conducted on two different subjects associated with suggested management alternatives in this thesis are reviewed in detail. The first alternative that is evaluated is centralizing pumps in the hospital in order for the departments to access required pumps through the central location. The first section of this chapter thus explores the literature on inventory and equipment pooling.

The second alternative that is assessed in this study is the use of Radio Frequency Identification technology (RFID) in order to achieve continuous real time object visibility. The second section of this chapter develops a solid understanding of RFID technology. Fundamental knowledge and technical aspects of this technology is explored and a number of its applications in health care industry and a few other areas are described.

3.1 Pooling Strategies

According to Benjaafar et al. (2005), "inventory pooling refers to the consolidation of multiple inventory locations into a single pooled location. Inventory locations may be associated with different geographical sites, different products, or different customers."

As stated by Tagaras and Cohen (1992), stock pooling is a common strategy for dealing with uncertainty in multilocation inventory systems. They mentioned that transshipment between locations is often used to spot shortage, and explained that pooling of stock is an alternative to expedited emergency shipments from different sources. In fact, different locations in an inventory management environment are comparable to hospital departments of this study. In the current situation at Grand River Hospital, demand for pumps is fulfilled by an emergency shipment of one or more pumps from the department with excess number of pumps to the department with the shortage. Therefore, in this section, research on different pooling strategies on both inventory pooling and equipment centralization is discussed.

3.1.1 Inventory Pooling

Eppen (1979) originated the concept of inventory pooling by studying a multilocation single-period newsboy problem with normal demand at each location. He assumed identical linear holding and penalty cost functions for each location and concluded that centralization of inventory could reduce the expected holding and penalty costs.

Tagaras (1999) analyzed the operation of a pooling group consisting of three retail outlets placing regular orders to a central warehouse every period. Collaboration among the retail outlets was in form of lateral inventory transshipment from an outlet with a surplus of on-hand inventory to an outlet that faces a stockout. The collaboration, after the demand was observed, was called emergency lateral transshipment, the purpose of which was to respond to actual stockouts. The redistribution of inventory between retailers before the realization of demand was called preventive lateral transshipment, the purpose of which was to reduce the risk of possible future stockouts. In his study, the cost of transshipment was lower than both the shortage cost and the cost of an emergency delivery from the central warehouse, and the transshipment time was shorter than the regular replenishment lead-time. He showed that lateral transshipment simultaneously reduced the total system cost and increased the fill rates at the retailers. The stocking locations that shared their inventory in this manner were said to form a pooling group since they effectively pooled their resources to reduce the risk of shortages and provided better service at lower cost.

In the current system at the Grand River Hospital, pumps are shared among departments. Pumps are moved from a department with excess of pumps to a department with shortage of pumps after the demand is observed. This method is called emergency lateral transshipment by Tagaras (1999). To avoid shortage overall, based on Tagaras' study (1999), when a department faces an excess of pumps, it should send the extra pumps to other departments that may have higher demand. This is in fact very difficult to control since the demand is very variable in each department, the hospital is a very fast paced environment, and without a central inventory control system, staff can not decide where to send the extra pumps.

In an earlier paper, Tagaras (1989) studied the inventory distribution systems with two locations, random demand and zero replenishment lead time. He showed that under certain conditions, complete pooling between the locations minimized the expected costs for the system. He derived the relationships between the measures of service level before and after pooling, and concluded that pooling always improved the service levels at both locations. He also studied the minimization of total costs subject to service level constraints. Tagaras et al. (1992) extended the former study by adding the assumption of nonzero replenishment lead time for each stocking location. They examined complete and partial pooling policies and concluded that complete pooling dominates partial pooling.

The importance of pooling was deeply studied by Alfaro and Corbett (2003) who addressed the effect of non-optimal inventory policies and the effect of demand that is not normally distributed on the value of pooling. They mentioned that pooling can be induced by serving multiple geographic locations, which is the situation of Grand River Hospital, or, by stocking multiple products. Their focus was on the latter case, which was the reduction of product variety, or in other words, consolidating all products into one. They performed a Monte Carlo simulation that allowed for a wide variety of demand patterns and found that the value of pooling under an optimal inventory policy is relatively robust across different demand distributions. They recommend that since finding an optimal policy is impossible, one should construct an estimate of potential benefits of pooling before implementing it.

Benjaafar et al. (2005) studied inventory pooling systems with identical costs. Their assumptions were that the demand arrives dynamically and supply lead times are endogenous and generated by a finite-capacity production system. They quantified inventory related cost savings that might be derived from consolidating inventory from multiple locations into one. They revealed that the value derived from pooling can be affected by utilization, demand and process variability, control policy of the order of fulfilling the demands, service levels, and the structure of the production process.

The study in this thesis differs, in a number of aspects, from the inventory pooling studies that were reviewed in this section. One difference is that in inventory pooling studies, the demand occurs when a location is out of stock, and there is at least one central source that can fulfill the demand of that location. In the hospital, on the other hand, the demand of each department is fulfilled from a constant number of available pumps in the system. These pumps are shared among all the departments. Another difference is considering a time to return the pumps to the central pool in the hospital. This time does not exist in inventory pooling studies, where the inventory of each location leaves the system. In fact, the hospital case study consists of the transshipment time between each of the two departments, for the current system, and the time to retrieve a pump from and return a pump to the central pool, for the pooling system.

3.1.2 Equipment Pooling

Pasin et al. (2002) studied the effects of equipment pooling on a group of local community service centers in the Montreal region. They used simulation as a tool to present the general and individual impacts of different forms of resource pooling in different demand scenarios. Local community service centers in their study did not face shortage. This was because they immediately compensated the lack of resources by renting from outside sources. However, rentals were more expensive than the use of internal resources. The authors quantified the benefits of pooling and showed that complete pooling was the option that would produce the lowest overall cost. By the time their paper was published, the pooling process was complete and all the equipment was stored in one place and shared by the participating community service centers.

The central pooling system suggested to the GRH is different from the study of Pasin et al. (2002). When each of the community centers needed a resource that was not available within their organization, they rented the equipment from outside resources, and the pooling system allowed them to use the equipment from other community centers. They only compared the renting cost to the cost of retrieving the equipment from internal resource, and ignored the distance between each two community centers, or later, the distance between each center and the central pool. At GRH, the departments are already sharing the resources and the costs to consider is searching for, and retrieving the pumps. The GRH study is considering more details in the cost calculation and is more applicable to healthcare settings such as hospitals.

An article by Gentles (2000) described medical equipment management in a hospital facing problems similar to the Grand River Hospital's. The author described the implementation of a central equipment pool for small equipment such as infusion pumps, feeding pumps, and portable suction units. The pool was managed by Sunnybrook and Woman's College Health Science Center Clinical Engineering Department. The author noted that before the implementation of the pool, nursing units were often frustrated by issues related to access to the technology. Also, the Biomedical Engineering Department that was responsible for repair services and maintenance, suffered from unnecessary workload when trying to perform preventive maintenance on infusion pumps. They spent more time searching for the pumps than servicing them.

A central pool with an inventory control using barcode technology was set up. New infusion pumps were purchased and a rental fee of US $0.67/day was charged to nursing units using new infusion pumps. This rental charge was calculated to equal the savings in set costs that nursing units would acquire by using new pumps instead of the ones existing in the hospital. Therefore, there would have been no net increase in nursing units' operating costs. The rental charge was originally set to recover the expenses of running the pooled system, (e.g. hardware, software, and labour) and was intended to prevent hoarding of pumps. A 20-minute pump delivery time was maintained for most departments, but a minimum stock or float of spare pumps was allocated to Emergency and ICU. These departments had a more critical need for pumps and needed immediate access to pumps.

The pooling system functioned for two years before the article was written and actual results were examined. The author pointed out the benefits of the pooling system including customer satisfaction and pump utilization improvement. Nursing staff were highly satisfied with the service, and requested pooling for other items as well. In addition, the hospital was managing almost twice as many infusions with the same number of pumps, which indicated the improvement in usage of their inventory of pumps.

Gentles (2000) has considered rental charges for the pumps that are borrowed from the central pool. This may prevent hoarding of the equipment, but this is a time consuming process that can affect the quality of service.

In another case, Fahlstrøm et al. (2006) described an implementation of an equipment pooling system in a hospital in Oslo, Norway. Their primary goals were better patient care and higher nursing quality. They organized a system where patient monitors, syringe pumps and infusion pumps traveled around in the hospital with the patients and were part of a central equipment pool when not in use. They allocated two storerooms for the pool; staff looking for equipment went to one of these places and picked up what they needed, or sent a porter to fetch it. No signature or paper record was required in order to save time.

The authors faced the problem of keeping detailed track of equipment, so their primary interest was in piloting a tracking system, where an ultrasound tag sent out a signal every time an object was moved. Receivers placed around in the building picked up this signal and staff could see where objects had last been moved, via a computer. This system worked well but required intensive installation work. Therefore, they decided not to proceed with this tracking system. The authors also observed that the system did not act as official documentation and some departments did not return their surplus items to the pool. After a trial period of six months, the authors concluded that a coordinator should walk around the hospital, pick up excess equipment, and return them to the pool.

The equipment pool successfully ran for 5 years. The pool eliminated problems including the shortage of equipment when required, time of nurses being wasted searching for equipment, finding the wrong type of equipment, and finding items being out of order or too dirty to be used. The authors concluded that patient safety was greatly enhanced. They also showed that the system was economically successful and pump utilization was higher than before.

The study of GRH is based on a simulation model that reflects the actual situation. The cost savings that occur due to reducing the search times are quantified. The distinct difference of this research with the studies conducted before is calculating the actual number of required pumps in the system. The number of pumps required is fewer than the number of pumps existing in the hospital. This results in a large capital savings for the hospital when replacing the current inventory with the newer model of pumps. It also proves that pump shortages occur due to behavioural issues, not insufficient inventory of pumps.

GRH is considering a different approach to manage this behavioural problem – the use of RFID technology. This technology is described in the next section.

3.2 Radio Frequency Identification (RFID)

Radio Frequency Identification (RFID) technology utilizes the radio portion of the electromagnetic spectrum to communicate data to allow wireless object identification. RFID technology offers various benefits such as improving item tracking and real time object visibility, increasing efficiency, and decreasing error. The history of RFID technology development, the components of the system and a number of its application will be discussed in the following sections.

3.2.1 History of RFID

RFID is not a new technology. Its first exploration dates back to World War II, when the British air force used radio technology to detect inbound enemy aircrafts. This was known as Friend or Foe. The theory of RFID was first explained in 1948 in a published paper by Harry Stockman (1948). In the paper he discussed the use of a reflected radio signal as a way to identify a remote object based on the reflection signature from the object. Other papers followed in the early 1950's speaking of systems in which a transmitted radio signal yields an identifiable, measurable, and recognizable return signal (Shepard, 2005). Development continued during the late 1960's when security and tracking was required for nuclear weapons. In the 1970's the public access to the technology spread and early adopters of RFID started its implementation by developing electronic identification systems. In the 1980's commercial applications of RFID developed (Datta, 2005). One of the first commercial uses of RFID was to tag livestock in an attempt to better track and monitor the health of individual animals (Gragg, 2003). The first RFID road toll collection was implemented in Norway in 1987, and was followed quickly in the United States by Dallas North Tumpike in 1989 (Landt, 2001). During the 1990's RFID technology continued to advance and many RFID standards emerged (Datta, 2005). In the early 2000's, RFID technology has been much more refined and has gained significant attention of more users. The year 2004 marked a significant shift toward adopting RFID because of mandates by large retailers such as Wal-Mart and Target, and government organizations such as US Department of Defense who required suppliers to implement RFID technology within the subsequent few years (Asif et al., 2005).

3.2.2 Components of RFID System

An RFID system is composed of three main components (See Figure 3-1).

- Tag or Transponder (transmitter/responder) which is attached to the item that needs to be identified.
- Reader (interrogator) that communicates with the tag by radio frequency signals and depending on the requirements can be a read, or write/read device.
- Software that sends commands to the reader and receives and interprets the data communicated by the reader. It is the interface between RFID system and enterprise applications.

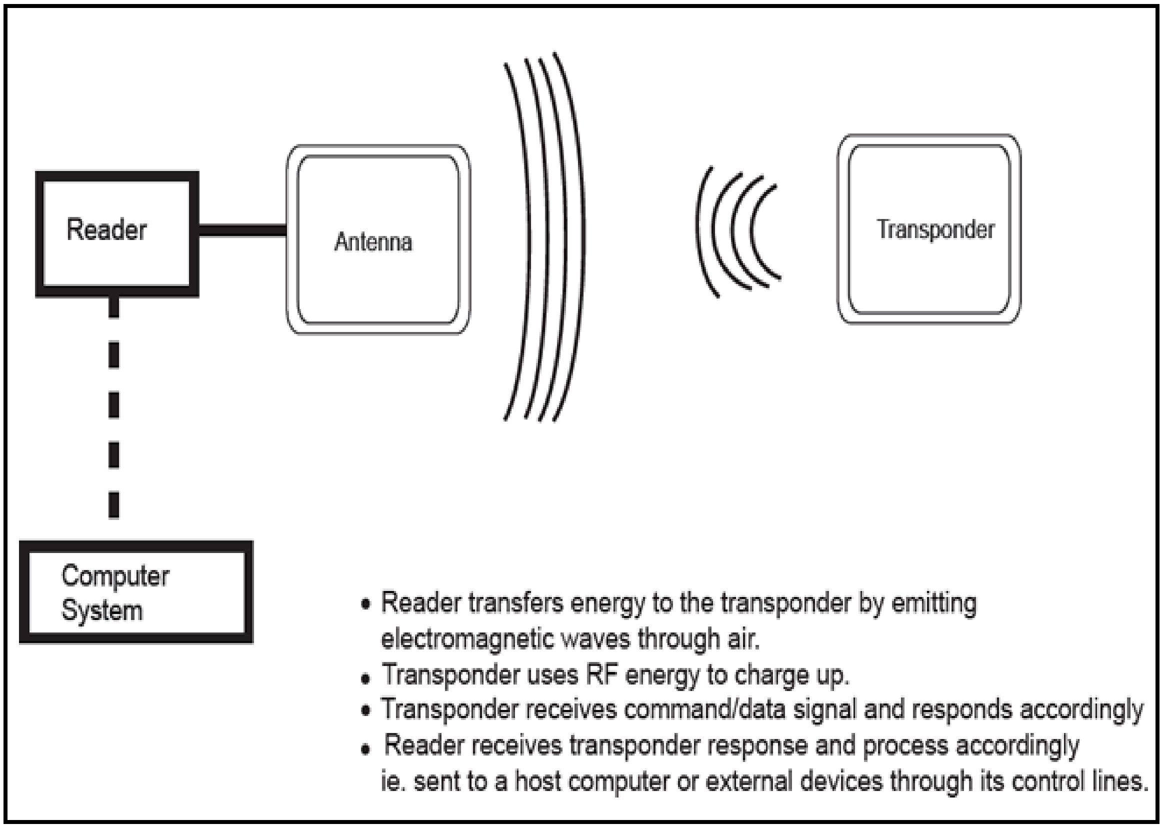


Figure 3-1: Components of an RFID system (Understanding RFID, 2004)

3.2.2.1 Tag or Transponder

The main component of RFID technology is the transponder or tag, which in most cases comprises of a chip and antenna mounted onto a substrate or an enclosure. The chip consists of a processor, memory and radio transmitter. Transponders are also known as smart or radio tags (Understanding RFID, 2004). Tags have different functional characteristics and come in variable construction formats such as discs and coins, keys and key fobs, glass tubes, smart cards and smart labels. Tags are mainly classified into two groups based on their source of power:

- Passive tags
- Active tags

Passive tags do not have their own internal power supply, therefore, the power required for operation of a passive tag must be drawn from the electrical/magnetic field of the reader (Finkenzeller, 2003). Passive tags are available with or without a chip. Active tags are self powered. They incorporate a battery to continually power the chip to transmit radio signals. There are also semi-passive RFID tags that contain a small battery that boosts the range and preserve memory (About RFID tags, 2005; Allen, 2005). Passive tags are lighter, smaller and less expensive than active tags. Passive tags also have a much longer lifespan and require less maintenance. However, passive tags have shorter read range and require a more powerful reader than active tags. Active tags, on the other hand, usually have larger memory capacity and better noise protection, and because of their onboard power, have greater communication distance. However, an active tag continually radiates its message to anyone who cares to listen. This raises multiple confidentiality issues (Gragg, 2003; Di Paolo et al., 2005).

Memory capabilities play an important role in transponder's application. For instance, the possibility of writing data to the transponder provides us with certain benefits. Transponders can either be Read Only (R/O) which are pre-programmed with a unique number (code), or they can be Read Write (R/W) for applications that require data to be stored in the transponder and to be updated dynamically. Another form of transponder is Write Once Read Many times (WORM). This will allow for an identification number to be written to the transponder once. In this case, the information that is stored in the memory cannot be changed but the transponder can be read many times (Understanding RFID, 2004). Read Only memory is usually incorporated into passive transponders, whereas, read-write memory is generally embedded in active transponders. Read Only transponders are less expensive than Read Write transponders since they do not require rewritable memory. Read Write tags are very useful for work-in-process tracking, since information stored in the tag can be changed or updated at different points of a process.

The data capacities of RFID transponders normally range from a few bytes to kilobytes. There are also chipless tags or 1-bit transponders. A bit is the smallest unit of information that can be represented and has only two states: 1 and 0. 1-bit transponders do not need an electronic chip, and a data quantity of exactly 1-bit signals two states to the reader:

“transponder in the field” or “no transponder in the field”. This is perfectly adequate to fulfil simple monitoring or signalling functions such as anti-theft systems in shops, or authenticating sensitive documents like intelligence reports and currency notes. These tags can be produced for about less than a penny (Finkenzeller, 2003; Asif et al., 2005).

3.2.2.2 Reader

An RFID reader, also called an interrogator, communicates with RFID tags within its reading range in order to obtain identification, location, and other information about the devices or products to which the tags are attached (About RFID readers, 2005) There are two types of RFID readers:

- Read-only readers
- Read-write readers

As the names suggest, read-only readers can only query or read data from a tag, whereas, read-write readers can both read from and write to the tags. To read passive tags, the reader emits radio frequency waves to its surroundings (interrogation zone) by its antenna to query the tags within its reading range. The antenna of the passive tags collects the radio frequency waves and uses RF energy to power up the microchip. Active tags utilize the energy of their built-in battery to power the microchip. The reader receives the signals transmitted by RFID tags and decodes the signals into data. The reader then transfers the data to a host computer for further processing. The reader reads all the tags within its read rang in a quick succession. This automatic process reduces read times (Asif et al., 2005). Readers can read up to 1000 tags per second, depending on the frequency of the system (RFID, 2005). Operating frequency is one of the most important characteristics of RFID systems. The operating frequency of an RFID system is the frequency at which the reader transmits RF waves. Tag’s transmission frequency is usually the same as the reader’s (Finkenzeller, 2003). The most important frequency ranges for RFID systems are: 0-135 kHz. (Low Frequency or LF), 13.56 MHz. (High Frequency or HF), 300 MHz.-3 GHz.

(Ultra High Frequency or UHF), and greater than 3 GHz. (Microwave). Microwave requires the use of active RFID tags (Understanding RFID, 2004).

Read-write readers, also known as encoders, can not only read information, but can also write (change) information in an RFID tag by sending a different signal to the R/W tag. Such RFID encoders can be used to program information into a "blank" RFID tag (About RFID readers, 2005). Typical read ranges vary from a few centimetres to a few meters. With active RFID tags, the read range can increase up to 200 feet. In general, the read range depends upon the following factors (Allen, 2005):

- Broadcast signal strength (Frequency of the system)
- Size of broadcast antenna (connected to or built in the reader)
- Size of transponder antenna
- The environment

The read range increases with the higher frequencies. Larger antennas broadcast the signals in a greater range. Therefore, if the antenna of the reader or the transponder is larger, the read range is greater. The environment plays an important role in RFID system performance. For instance, metal, electrical noise, extreme temperatures, liquids and physical stress can affect the function of RFID system and increase the error rate (Understanding RFID, 2004). In multi-antenna systems coupling between antennas may occur. This can be minimized by locating the antennas exactly 90º to each other (Tag-it FAQs, 2006).

Readers are found in various forms: they can be fixed for stationery applications, like a frame that covers an entrance gate, or they can be portable, like a handheld reader.

3.2.2.3 Software

Software that is installed on a host computer is the feature that integrates the components of an RFID system. All reader and transponder activities are initiated by the application software (Finkenzeller, 2003). Software performs a set of applications useful to the enterprise. It sends commands to the reader, receives data from the reader, enters the data into a database, and provides access to the data in various desired ways (Finkenzeller, 2003; Shepard, 2005).

If the number of tags simultaneously entering into the interrogation zone of a reader is high, "data collision" may happen. "A collision is the situation that occurs when two or more devices attempt to send a signal along the same transmission channel (the path between two nodes on a network that data communication follows) at the same time. The colliding of the signals can result in garbled, and thus useless, messages (Collision definition, 2005)." Software is responsible to manage the high volume of data and prevent errors such as duplicate or false reads. The Auto-ID center at MIT has developed a software program named "Savant" that filters and manages the data and forwards only clean data in order to avoid application problems (Asif et al., 2005).

3.2.3 Applications of RFID Technology

RFID technology has a vast number of potential applications and can bring major benefits to different industries. A few of its application in different areas is summarized below.

RFID improves tracking and provides product visibility and traceability. Transportation industry gains many advantages from the implementation of RFID for tracking goods moving from one location to another. For instance, airlines are developing methods of implementing RFID into luggage tags in order to reduce the amount of lost luggage. In health care, patient, staff, and asset tracking can be facilitated using RFID technology. Proper asset tracking enhances the quality of patient care and increases efficiency. Proper patient tracking is critical, especially when urgent medical attention is required.

RFID can be used against counterfeiting and theft. For instance, embedding RFID tags into items in a retailer makes theft much more difficult. Valuable assets in a hospital can also be equipped with RFID tags to be protected from theft. Baby abduction is another important issue to which RFID can be a solution. By attaching RFID tags to babies and children in maternity and paediatric units, the risk of abduction is significantly reduced. The way this system works is that when a tag is going to exit its permitted area, the alarm starts working, and in some cases doors and elevators are automatically locked.

Drug counterfeiting is an issue that pharmaceutical industry has been facing for some time. This problem not only results in significant loss in profit for the pharmaceutical companies, but also is a major threat to the health of people around the globe, who use these drugs. Embedding RFID tags into product packaging make it possible to track and trace the movement of every package of drugs from production to dispensing.

RFID can also be used in security keys and access control. Access security has been used in automobiles in recent years. In a hospital, access to restricted areas can be controlled by giving RFID badges to the permitted staff.

One of the important applications of RFID in health care is patient identification. The US Navy has used HF technology to track the status and location of wounded soldiers in Iraq. They used a system that enabled a healthcare team to identify patients from their RFID-enabled wristbands and to update patients' status, location, and medical information in the system automatically. This system can be used, as well, in hospitals to improve quality of patient care. For instance, blood transfusion errors are prevented using this system. RFID readers read the tag on the blood bag and the tag on the patient's wristband and check whether both blood types match each other. An alarm is triggered if a mismatch is observed.

In summary, RFID can bring many advantages to our daily life. Although there are still barriers such as cost, standards, or even lack of familiarity slowing widespread adoption of RFID technology, it is rapidly improving and being applied by more and more users day after day.

3.3 Summary

The first section of this chapter reviewed studies previously conducted on inventory pooling and equipment pooling. The conclusions that were made in each of these studies were investigated and compared with the results of centralized pooling system suggested to the Grand River Hospital (GRH). It was concluded that quantifying the actual quantity of equipment required in a system has not been carried out in previous research.

The second section of this chapter described the Radio Frequency Identification (RFID). RFID technology is one of the alternatives that GRH can use for proper pump management. RFID technology provides continuous real time object visibility and can be used to locate pumps throughout the hospital. General information about the components of an RFID system, its history, and a number of its application in different areas, including health care industry, were reviewed.

Chapter 4: Model Development

This chapter describes the process by which a model of the pump flow through the Grand River Hospital was created. First, to gain a better understanding of the key elements of the system, the details of flow of patients and pumps were described and modeled. Next, because of the complexity of the system, and the need to compare several different pump management schemes, a simulation model was developed for subsequent analysis.

Data collection and input data analysis were performed along with the model development process. The model reflecting the current system was then operationalized into a simulation model in the Simul8 environment. The chapter concludes with a discussion of the procedures used to verify and validate the simulation model.

4.1 Flow of Patients and Pumps

To be able to develop a simulation model, it is necessary to have a thorough understanding of the system and its elements. This section provides an overview of both pump flow and patient flow through the hospital. Components of the system are introduced and a model that reflects the system is developed.

4.1.1 Overview

The model was constructed based on the actual system of pump management at Grand River Hospital. Understanding of the system was achieved by observation and interviewing the clinical directors in the hospital. Through this process, it was concluded that the patient flow and the pump flow can be studied on a daily basis and this level of detail was sufficient to provide reasonable results for the analysis. Therefore, the data collection was performed on a daily basis and the simulation time unit was considered "one day." The data that were utilized in the model consisted of: the number of patient arrivals to each department per day, the length of stay of each patient in every department, the number of pumps required per patient, and daily number of patient departures to other departments or to discharge that provided the flow of patients between departments or discharge. The process of data collection is thoroughly described in Section 4.2.

4.1.2 Modeling the Current System

To study the patient flow in the hospital, the first step is to identify the entry points of patients into the hospital and into each patient care department.

One major admission site is the Emergency department. In general, two groups of patients arrive to the Emergency department; one group includes patients whose injury can be treated within one day and don't need to stay overnight (outpatients). They are treated in the Emergency department and released on the same day. Since the model only captures inpatient flow, this group will not be considered in the study.

The second group of emergency arrivals consists of patients who need more extensive care and should stay overnight (inpatients). A very small number of these patients stay overnight in the Emergency department. Most inpatients who enter to the Emergency department receive primary treatment, and are then transferred to another department according to their illness. For example, a number of these patients undergo surgery, so they are sent to the Operating Room (OR). After the operation, they go to the Post Anastasia Care Unit (PACU) for a short period of time to recover. Subsequently, they are sent to the General Surgery department for post-surgery care. These patients appear in the hospital records as being transferred from Emergency to General Surgery.

Another admission point is Day Surgery. Patients who are scheduled for an operation go to Day Surgery Unit and prepare for their operation. They are then sent to the OR department for their operation, and then to PACU for primary recovery. Patients who undergo a minor operation and who do not need to stay overnight are sent back to Day Surgery and then released home. The remainder of the patients are transferred to three departments: General Surgery, Paediatrics, or ICU, depending on their status. These patients appear in the hospital records as arriving to the Day Surgery department.

Departments also admit patients directly from outside the hospital. In the model, this entry point is a “direct admit.” For instance, transfers from other hospitals, or doctor referrals fall into this category.

In addition to admissions from outside the hospital, departments admit patients from other departments in the hospital. Many patients stay a few nights in one department and then move to another before they are discharged. This is referred to as a “transfer.” Finally, patients that are released from the hospital either return home or move to other care facilities. All released patients are considered as “discharge.”

Besides the admissions and discharges, the flow of patients in the hospital occurs between six departments. These departments are: CCU, General Surgery, ICU, Medical Program, Oncology, and Paediatrics. Another reason to consider only these six departments is that the model is focused on pump utilization, therefore, units that typically do not utilize any pumps and do not have patient flow from the model’s main departments are ignored in the model. An example is Psychiatry department. It is not a heavy user of pumps, and rarely admits patients from the model’s six departments.

There are several units in the hospital that intensively utilize pumps and are not taken into account in the model. These units are the Cancer Center, Retail Pharmacy, and Neonatal Intensive Care Unit (NICU). The primary reason for excluding these departments from consideration is that they do not share pumps with other departments, nor was it considered appropriate that they do. While these departments keep a number of pumps for their utilization, there are various reasons these pumps and departments were removed from consideration. The Cancer Center, located next to the main building of the hospital, uses essentially the same number of pumps each day for chemotherapy treatments. Due to inconvenient access from the main building to the Cancer Center, it is reasonable for the Cancer Center to keep its own stock of pumps. As for the Retail Pharmacy, it loans pumps to patients staying at home. The Pharmacy keeps its own stock of pumps due to the high loan-out rate. Similarly, NICU has a set of pumps that are specially adjusted for newborn baby utilization. The number of pumps held by these three departments has been deducted from the total number of pumps in the hospital to more accurately reflect the total number of pumps shared by the remaining departments.

Based on the discussion above, the model of patient and pump flow through the hospital consists of the following components:

- Six major patient care departments, including CCU, General Surgery, ICU, Medical Program, Oncology, and Paediatrics.
- Arrivals: two departments that act as entry points for the six patient care departments, Emergency and Day Surgery departments, and direct admit points for each of patient care departments.
- Length of stay of patients.
- Number of pumps used by each patient.
- Flow of patients between departments.
- Discharge.

On a typical day, a number of inpatients, who are attached to a number of pumps, are staying in each department. In the current situation, when a patient is released from a department, the pumps that are disconnected from the patient remain in that department until being retrieved again. When a patient is admitted in a department, first the number of pumps that is required for that patient is evaluated. If pumps detached from the released patients were available in that department, the staff utilize those pumps for the new patient. But if there are not sufficient pumps for this new patient, the department encounters a shortage of pumps and its staff should retrieve required pumps from another location (department) in the hospital. In the model, all arrivals and discharges occur in one time unit (one day). Therefore, at the beginning of a day (time unit), a number of patients are admitted into each department. If the number of pumps required for these new patients is equal to the number of freed up pumps by the patients release at the end of the previous day, the department has zero shortage or excess of pumps on that day. If the number of freed up pumps by the released patients is more than the number of pumps required by the new patients, the department encounters an excess of pumps on that day. And, if the number of freed up pumps was fewer than the number of pumps required by the new patients, the department experiences a shortage of pumps. Therefore, when a department encounters shortage of pumps, its staff need to retrieve pumps from other locations of the hospital.

At present, Grand River Hospital owns a total of 317 pumps. There is no departmental ownership of pumps. However, as explained earlier, a number of pumps are held by three departments and are not shared among all departments (NICU: 20 pumps, Pharmacy: 32 pumps, and Cancer Center: 30 pumps). Also, pumps have a preventive maintenance procedure performed annually by Biomedical Engineering department. If a pump breaks during use, the corresponding department replaces it with a new pump and attaches a sheet to the broken pump that indicates the need for repair. The department then sends the pump to Sterile Processing Department (SPD) for decontamination process. The clean broken pump is collected by Biomedical Engineering staff. Once the pump is fixed, it is returned to SPD for redistribution. Usually, cleaning process is done within the department in order to save time sending the pump to SPD. Each time a pump is disconnected from one patient, housekeeping staff wipe the pump with standard hospital disinfectants. This pump is then ready to be utilized for another patient. However, seldom, when a pump can't be cleaned within the department, it is sent to SPD for cleaning. Clean pumps remain in SPD dispatch area and are picked up by patient care departments when required. The number of pumps that are broken or in preventive maintenance procedure was calculated. 4 pumps are out of order on each day. In addition, each of the 7 operating rooms has one pump kept in, for operation purposes (total of 7 pumps). The total number of pumps held by NICU, Pharmacy, Cancer Center, Operating Rooms and Biomedical Engineering was deducted from the total number of pumps in the hospital. As a result, the number of pumps available in the system was 224.

The Emergency department is one of the primary entry points of patients to the hospital. This department accepts patients from outside the hospital and sends them to other departments based on their needs. Nearly 80% of the patients transferred from the Emergency department to the other departments take one pump with them. Therefore, the Emergency department is in constant need for pumps. In addition, since a number of patients admitted into departments from the Emergency department are attached to a pump, the number of required pumps for these patients is evaluated considering the one pump that is already attached to them.

As explained earlier, patients are admitted into departments, receive their treatments, and then are released from that department. The released patients are either transferred to another department base on their needs, or discharged from the hospital. Transfers between the departments form the flow of patients between departments, and discharges are going home or to other care facilities. Whenever patients are released from a department, they are disconnected from all the pumps attached to them. If the patients are transferred to another department, their pump requirement is evaluated again in the new department. Figure 4-1 presents the flowchart of the patient and pump flow from the patient's view point. Figure 4-2 demonstrates the flowchart of the patient and pump flow from the department's perspective.

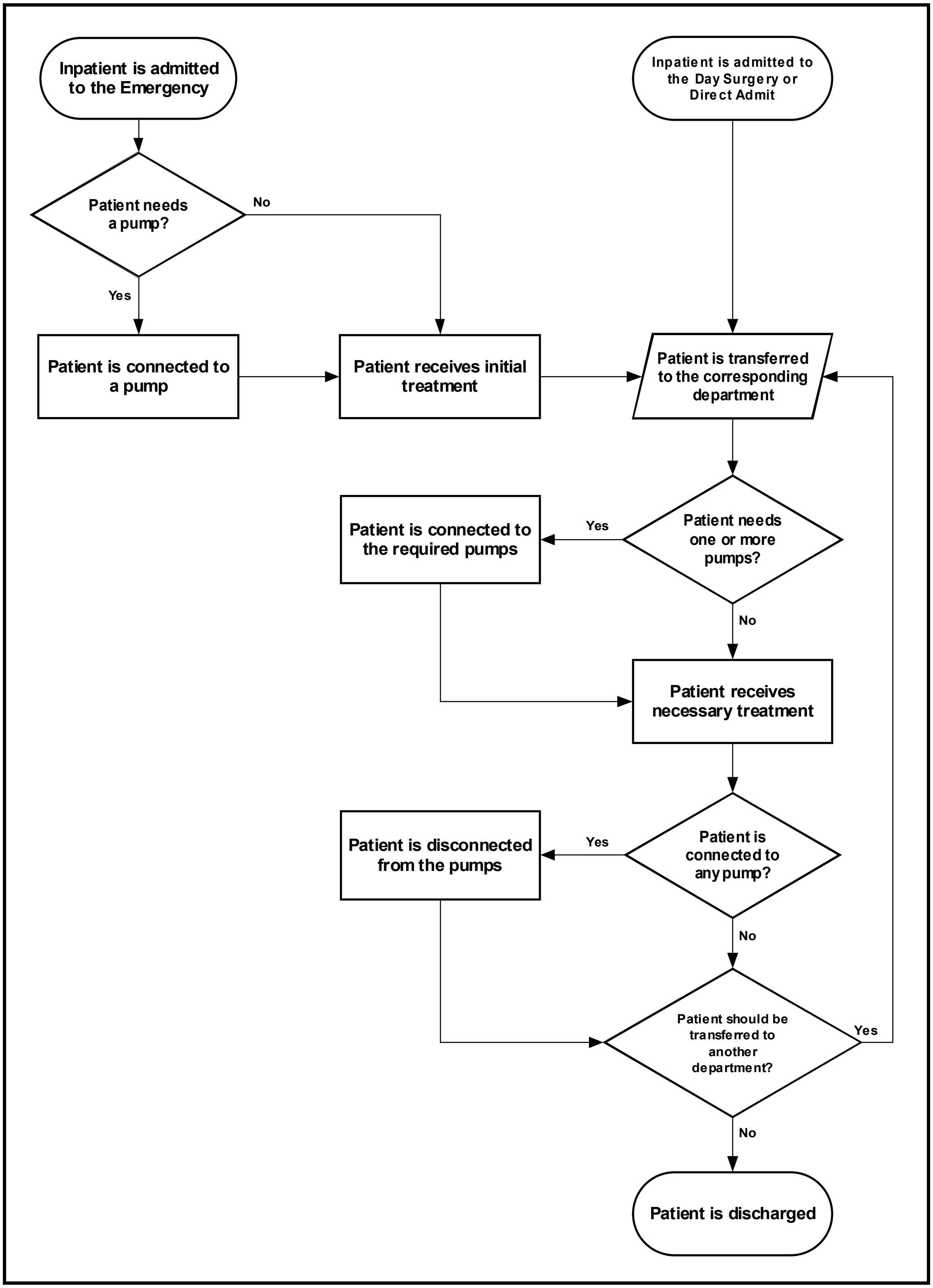


Figure 4-1: Flow of Patients and Pumps from Patient's Perspective

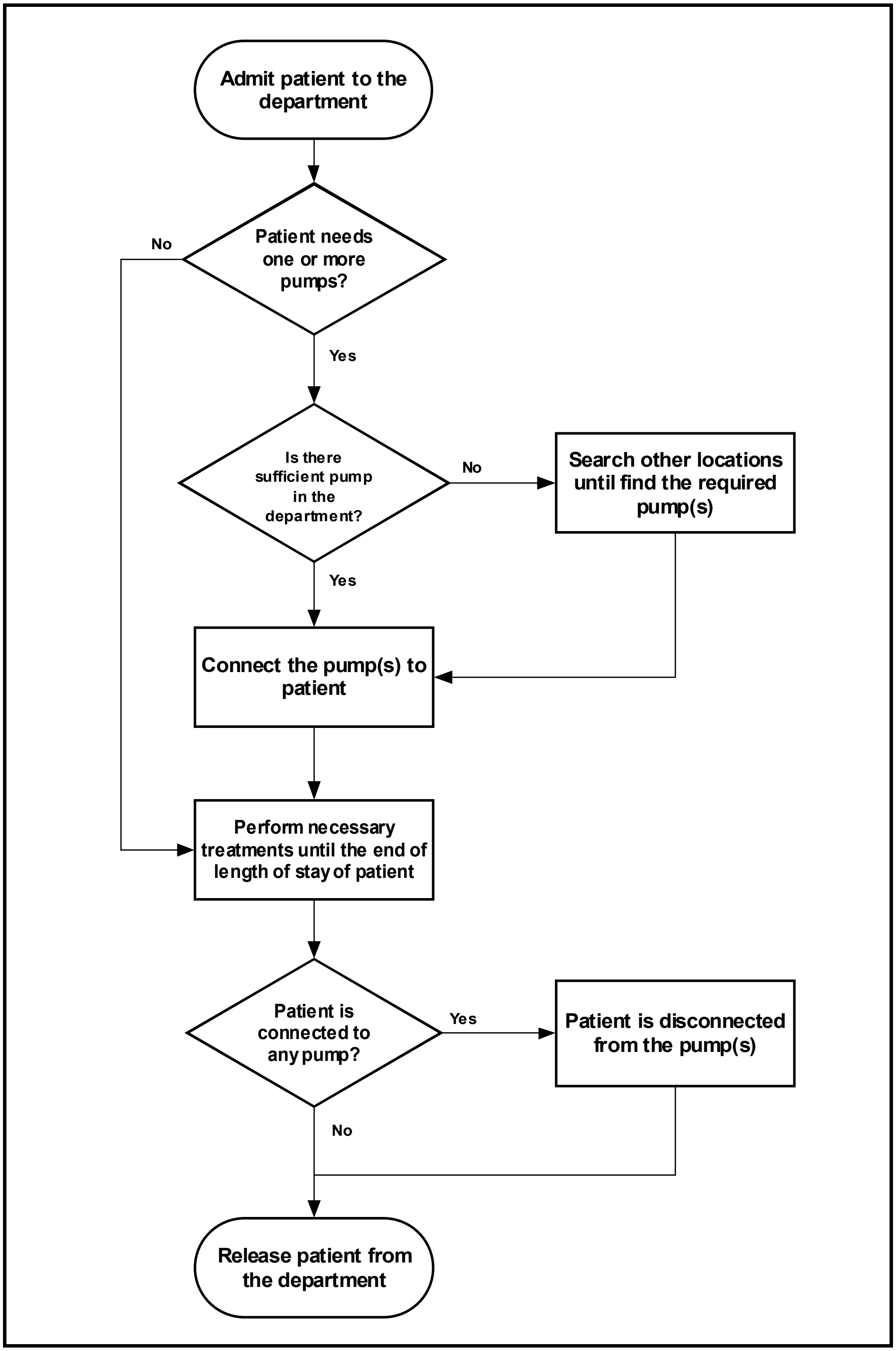


Figure 4-2: Flow of Patients and Pumps from Department's Perspective

Figure 4-3 provides a visual presentation of entry, transfer, and discharge paths patients may take. In this figure, each department is shown by a different color. The flow of patients is illustrated by arrows. Arrows play different roles in this representation. Dotted arrows show “direct admits” into each department. In the simulation model, the number of patients who are directly admitted into a department on a daily basis can be modelled by a discrete probability distribution that has been fitted to hospital data. Double line arrows show the flow of patients from Emergency and Day Surgery. The number of patients coming from Emergency and Day Surgery has also been derived from the distributions fitted to the data collected from each of the patient care departments. The third arrow type is a continuous line with variable thickness. This type of arrow shows the flow of patients between patient care departments. The thickness of the arrow connecting two departments provides the percentage of the total patients out of the source department who are transferred to the end department.

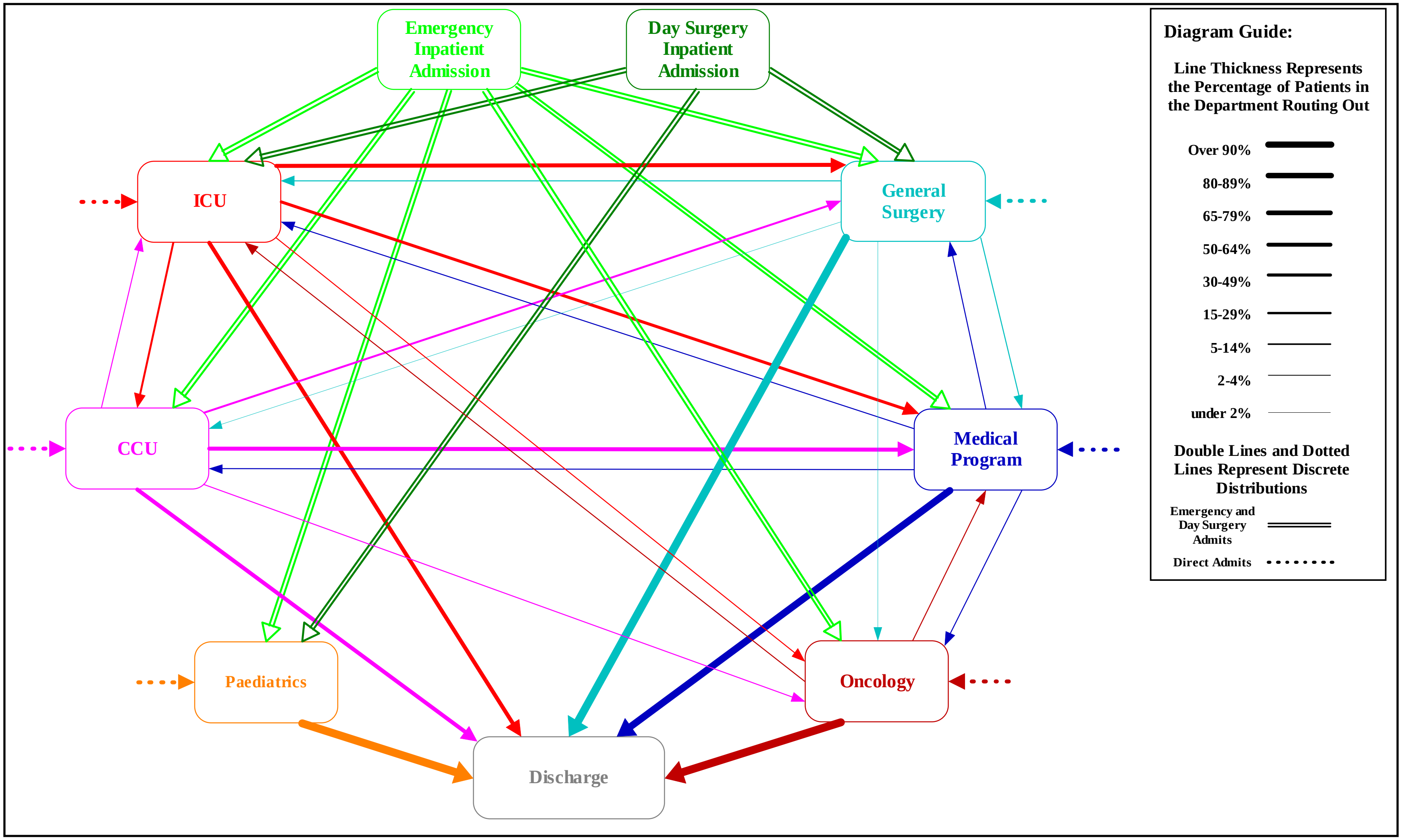


Figure 4-3: Patient Flow Diagram

4.2 Data Collection

To develop a simulation model that accurately represents the real system, proper and sufficient data should be collected. The level of detail in data gathering depends on first, the structure of the model, and second, the available time and resources. In this study, data collection and model development were performed concurrently. One reason was that the required level of complexity for the model determined iteratively during the process of studying the system. In addition, the availability of actual system data was also taken into consideration. According to Banks et al. (2005), “data collection is one of the biggest tasks in solving a real problem.” The authors mention that even when data are gathered, they are rarely in a format that can directly be used for simulation input modeling. This was certainly the case for this study.

Three groups of data were required to develop the model:

- The volume and direction of patient flow.
- Patients’ pump requirements.
- Expected length of stay of patients.

Patient flow volume consists of the number of patients admitted into departments from all the entry points, the number of patients transferred in-between departments, and the number of patients released from each department. These data existed in the hospital databases on a daily basis. The data were detailed enough to provide necessary insights for the simulation model. Electronic data were provided in three spreadsheets for a period of 121 days. One of the spreadsheets contained daily direct admits to the departments. These data were then converted into probability distributions of the number of daily direct admits into each department. The second spreadsheet contained the number of transfers from each department to other departments. Since Emergency and Day Surgery act as entry points to the other six departments, transfers from Emergency and Day Surgery were the basis of admission probability distributions. The number of patients transferred between the departments provided both the direction of patient flow, and the volume of patients transferred from each department to others. The third spreadsheet included daily discharges from departments to outside of the hospital. All the data from the spreadsheets were then transformed into appropriate format to be useful as input for the simulation model.

Information about the number of pumps required by each patient was not recorded in any document. In fact, this was one of the reasons that this study was raised. The number of pumps in use within each department and by each patient was gathered through interviews with clinical directors of each of the departments of the study. The information they provided was based on their knowledge and experience. In addition to initial interviews, questionnaires were arranged in order to clarify any ambiguity left after the interviews and during the modeling process. The data gathered from the interviews and questionnaires were then analyzed to form probability distributions that best reflected the actual circumstances.

Information about the length of stay of patients in each department was also acquired from the clinical directors. They provided the most likely, average, minimum, and the maximum number of days that patients stayed in their department. From this information, empirical probability distributions representing the length of stay for each of the patients admitted into departments were derived and the average was confirmed against data.

4.3 Input Data Analysis

Most real systems have at least one source of randomness (Law & Kelton, 1991). The system in this study employed a number of random variables used as inputs to the simulation. These included the volume and frequency of patient arrivals, the patients' length of stay, and the number of pumps used for each patient. To conduct a simulation, it was necessary to specify probability distributions for each of these sources of randomness.

It is important to choose probability distributions that accurately reflect the actual data in order for a simulation to yield useful results. Even though it is difficult to determine the true probability distribution for a random variable in a real application, model developers try to fit the closest distribution to the actual data.

Input probability distributions can be identified by different procedures to evaluate how well they represent the actual data distributions. “Standard techniques of statistical inference are used to fit a theoretical distribution form to the data and to perform hypothesis tests to determine the goodness of fit (Law & Kelton, 1991).” Goodness-of-fit tests are techniques to evaluate how suitable a potential input model is.

The first step in fitting data to a theoretical distribution is to construct a frequency distribution or histogram in order to identify potential probability density function or probability mass function. A series of known distributions can then be compared to the histogram. At present, distribution fitting programs are widely available to facilitate this process. In some occasions, when no theoretical distribution fits the data effectively, the observed data can directly be utilized to form a distribution called an “empirical distribution.” To define an empirical distribution for discrete data, for each value x, an empirical mass function $p(x)$ can be identified to be the proportion of the X_i*’s* that are equal to x (Law & Kelton, 1991).

In this study, two methods were employed to identify the input probability distributions. The first method was fitting theoretical distribution models to the actual data of patient flow for each of the entry points. This method was performed using ExpertFit, which is a distribution fitting software. The second method was to define empirical distributions using actual data of pump requirement and patients’ length of stay for each of the departments. For entry points, data were inserted into ExpertFit and a set of discrete distributions were derived. These distributions were approximations of actual input distributions. The program then evaluated each of the distributions and their associated parameters for goodness-of-fit. Goodness-of-fit can, in general, be evaluated by two general methods: graphical comparisons, and statistical tests (Law & Kelton, 1991).

One type of statistical test is a Chi-square test. It is the formal comparison of the histogram of the data to the shape of the candidate density or mass function (Banks et al., 2005). A Chi-square test was employed for evaluation the best distribution of each entry point. A summary of result for this test can be found in Appendix B. Detailed information about this statistical test can be found in Law & Kelton (1991).

A number of graphical comparison techniques were also used for input data distributions. Two types of these methods are presented in Section 4.3.2.

4.3.1 Input Probability Distributions

In this section, the fitted probability distributions used for input process for the simulation model are introduced. There are six departments in this study. Each of these departments has direct admits and admits from the Emergency department. Day Surgery is also the entry point for three of the departments; therefore, a total of 15 entry points exist. Each of these entry points requires one probability distribution that is part of the input data process for the simulation model. To obtain these 15 distributions, data were input into ExpertFit, and a number of discrete distributions were returned for each of the entry points. ExpertFit assigns a relative score to each of the candidate distributions in order to identify how closely they fit the underlying distributions. Table 4-1 shows the best fitted distribution suggested by the program for each of the entry points. The first column of this table shows the entry point. The second column gives the distribution that best fits the actual data. The third column provides the relative score of each model. The score ranges from 0 to 100. The fourth column shows the model parameter that differs for every distribution model. The last column is the estimated value for each of the model's parameters.

Table 4-1: Input Data Distribution Models – Entry Points

Entry Point	Model	Relative Score	Parameter(s)	Value
Direct Admit to CCU	Negative Binomial	77.78	Probability	0.8963
			Success	6
Direct Admit to General Surgery	Negative Binomial	88.89	Probability	0.476
			Success	5
Direct Admit to ICU	Negative Binomial	77.78	Probability	0.90977
			Success	4
Direct Admit to Medical Program	Negative Binomial	100	Probability	0.50787
			Success	4
Direct Admit to Oncology	Negative Binomial	88.89	Probability	0.52723
			Success	2
Direct Admit to Paediatrics	Negative Binomial	77.78	Probability	0.69674
			Success	3
Emergency to CCU	Binomial	88.89	Probability	0.11639
			Trial	12
Emergency to General Surgery	Negative Binomial	88.89	Probability	0.89414
			Success	40
Emergency to ICU	Poisson	77.78	Lambda	0.68595
Emergency to Medical Program	Negative Binomial	100	Probability	0.88998
			Success	47
Emergency to Oncology	Negative Binomial	77.78	Probability	0.73556
			Success	2
Emergency to Paediatrics	Poisson	88.89	Lambda	2.47107
Day Surgery to General Surgery	Discrete Uniform	100	Lower endpoint	0
			Upper endpoint	18
Day Surgery to ICU	Poisson	77.78	Lambda	0.28099
Day Surgery to Paediatrics	Geometric	61.11	Probability	0.93077

Empirical distributions were also defined for patient pump requirements in each of the departments. “Pump requirements” specify the probability distribution of the number of pumps each patient requires during his or her stay in the department. Figure 4-4 through Figure 4-9 show the patient pump requirement distributions for each of the six departments in the study. Table 4-2 shows the descriptive statistics of patient pump requirement distributions by department.

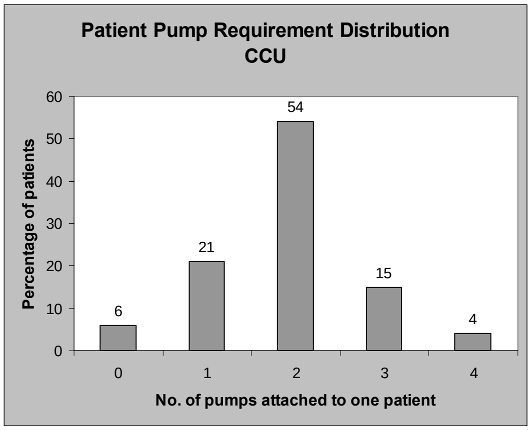


Figure 4-4: Patient Pump Requirement Distribution - CCU

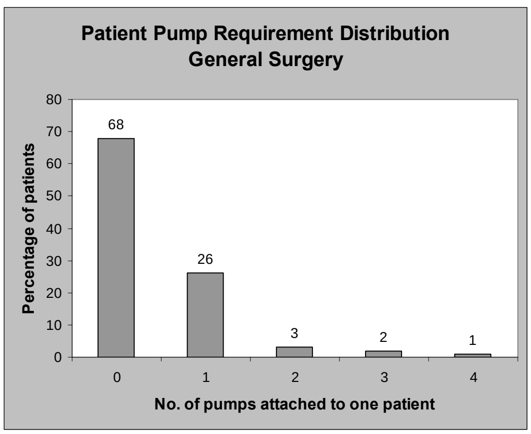


Figure 4-5: Patient Pump Requirement Distribution - General Surgery

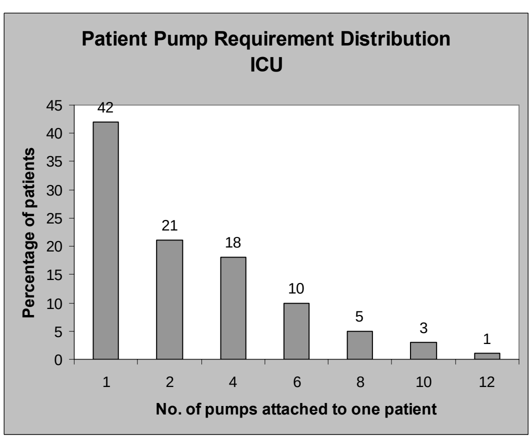


Figure 4-6: Patient Pump Requirement Distribution – ICU

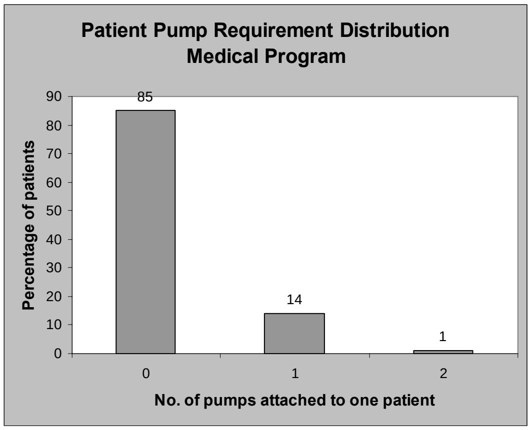


Figure 4-7: Patient Pump Requirement Distribution - Medical Program

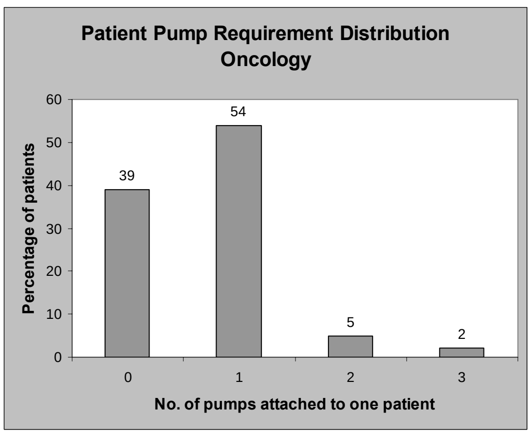


Figure 4-8: Patient Pump Requirement Distribution - Oncology

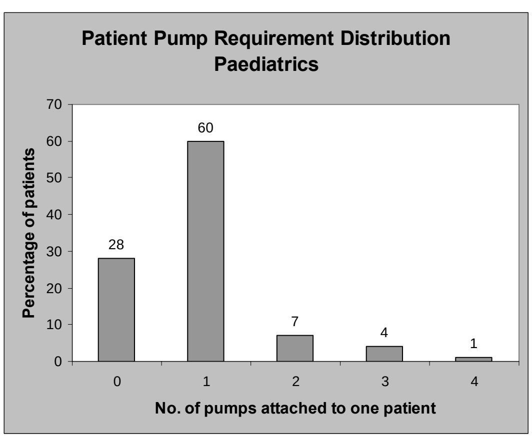


Figure 4-9: Patient Pump Requirement Distribution – Paediatrics

Table 4-2: Descriptive Statistics of Patient Pump Requirement Distributions by Department

Department	Mean	Mode	Standard Deviation	Sample Variance	Confidence Level (95.0%) Half-width
CCU	1.90	2	0.87	0.76	0.17
General Surgery	0.42	0	0.74	0.55	0.15
ICU	2.98	1	2.56	6.57	0.51
Medical Program	0.16	0	0.39	0.16	0.08
Oncology	0.70	1	0.66	0.43	0.13
Paediatrics	0.90	1	0.77	0.60	0.15

Empirical distributions were also defined for patients' length of stay. Patients' length of stay specifies the probability distribution of the number of days a patient stays in a department. The "Geometric" distribution with the probability of 0.119 was a good fit to the data for the Oncology department. For the rest of the departments, empirical probability distributions were defined. Figure 4-10 through Figure 4-14 show the patients' length of stay empirical distributions for five departments. Table 4-3 shows the descriptive statistics of patients' length of stay empirical distributions by department.

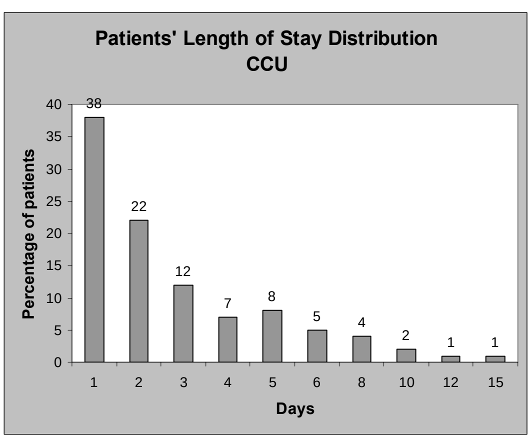


Figure 4-10: Patients' Length of Stay Distribution - CCU

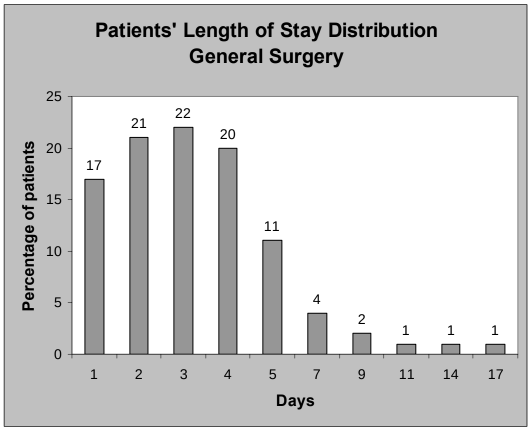


Figure 4-11: Patients' Length of Stay Distribution - General Surgery

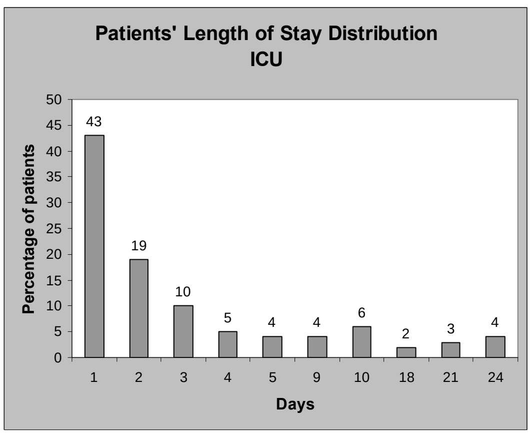


Figure 4-12: Patients' Length of Stay Distribution - ICU

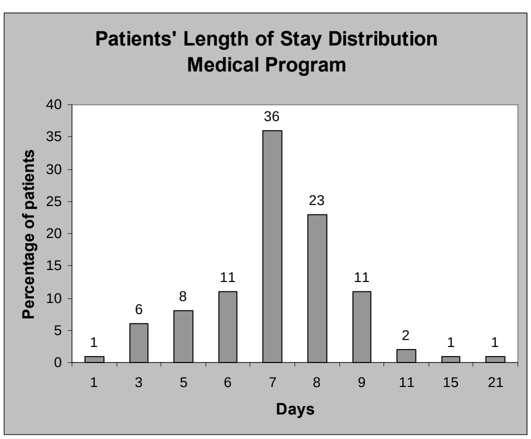


Figure 4-13: Patients' Length of Stay Distribution - Medical Program

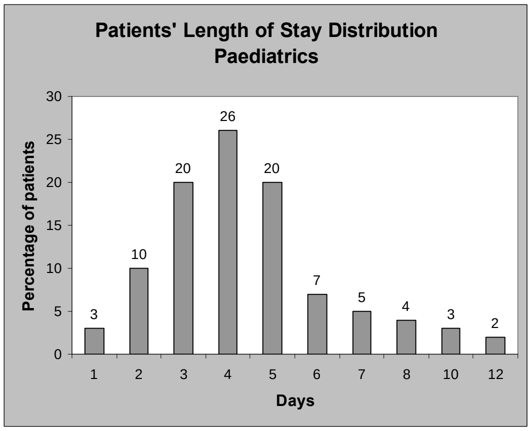


Figure 4-14: Patients' Length of Stay Distribution – Paediatrics

Table 4-3: Descriptive Statistics of Patients' Length of Stay Empirical Distributions by Department

Department	Mean	Mode	Standard Deviation	Sample Variance	Confidence Level (95.0%) Half-width
CCU	2.95	1	2.62	6.88	0.52
General Surgery	3.48	3	2.56	6.53	0.51
ICU	4.42	1	6.06	36.71	1.20
Medical Program	7.18	7	2.32	5.36	0.46
Paediatrics	4.50	4	2.14	4.60	0.43

4.3.2 Graphical Comparisons

One of the methods to examine how well the selected theoretical distribution matches the distribution of actual data is graphical comparison of the two distributions. Two types of these graphical procedures are discussed in this section: frequency comparison plots, and probability plots. "For discrete data, a frequency comparison is a graphical comparison of a line graph of the data with the mass function of a fitted distribution (Law & Kelton, 1991)." One type of probability plot that is presented in this study is probability-probability plot or P-P plot. "A P-P plot is a graph of the model probability versus the sample probability (Law & Kelton, 1991)." Figure 4-15 through Figure 4-29 represent frequency comparison plots and P-P plots side by side for each of the 15 entry points of the system. The format of the plots is predefined in ExpertFit. These plots show that the probability distributions fit the data relatively well. Only Figure 4-27, which represents Day Surgery admit to General Surgery, illustrates a not well fitted distribution to the data. The data of Day Surgery admit to General Surgery were dispersed and formed a unique distribution. Due to these characteristics of the data, discrete uniform was the best distribution fitted to these data. Although discrete uniform distribution is not graphically a good fit, the number of patients it produced in the simulation model was close to the actual number of patients that were admitted to the General Surgery through the Day Surgery Department.

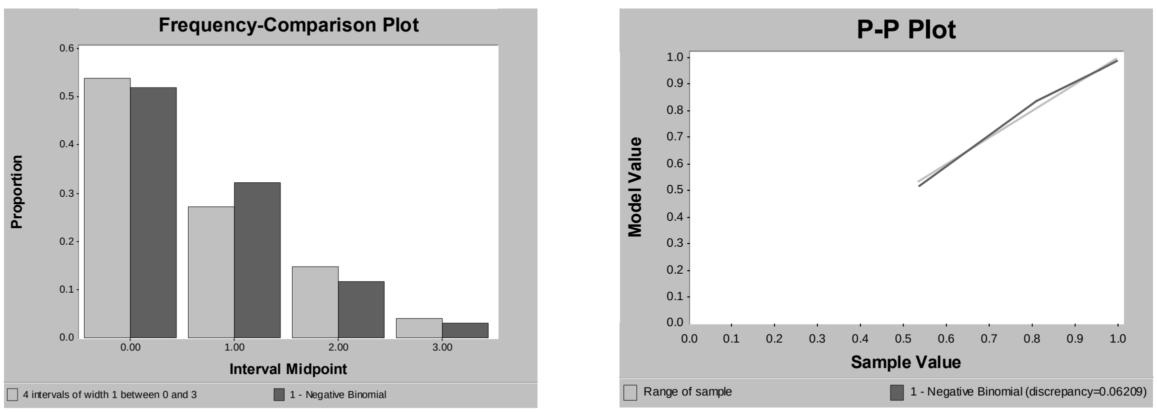


Figure 4-15: Frequency-Comparison Plot and P-P Plot, Direct Admit to CCU

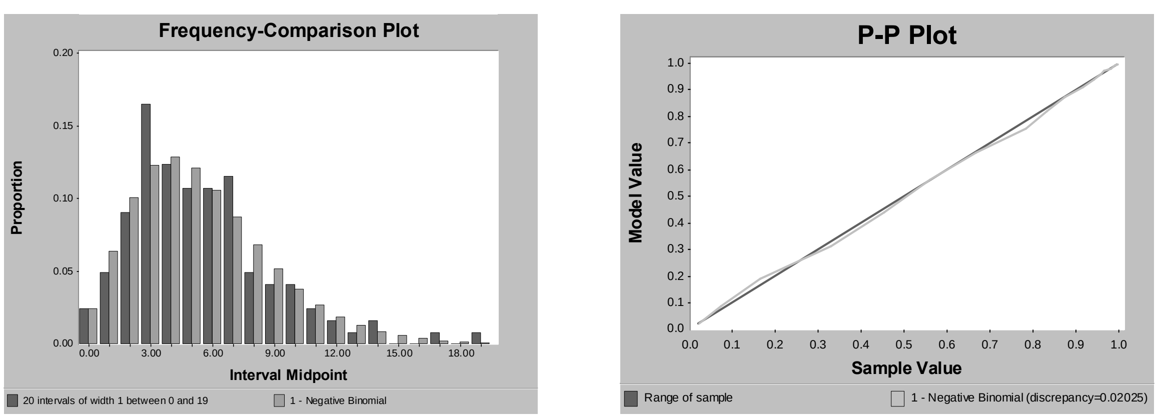


Figure 4-16: Frequency-Comparison Plot and P-P Plot, Direct Admit to General Surgery

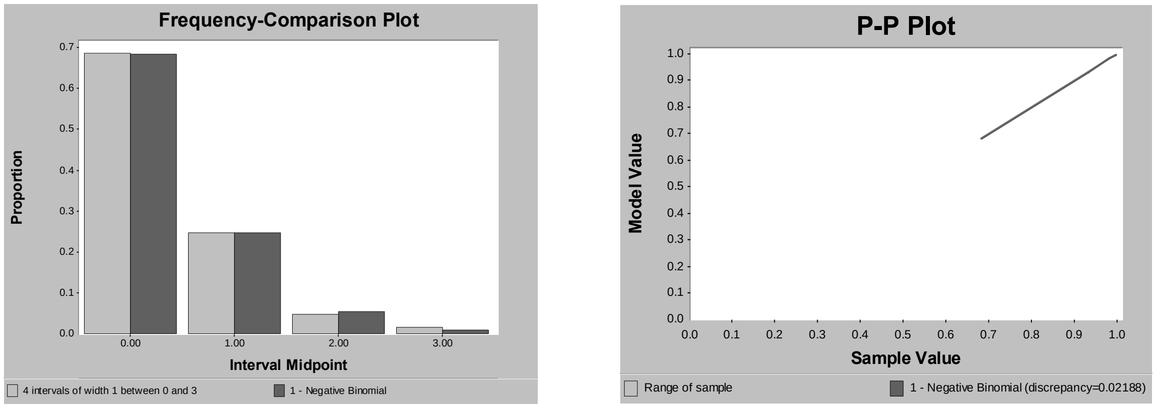


Figure 4-17: Frequency-Comparison Plot and P-P Plot, Direct Admit to ICU

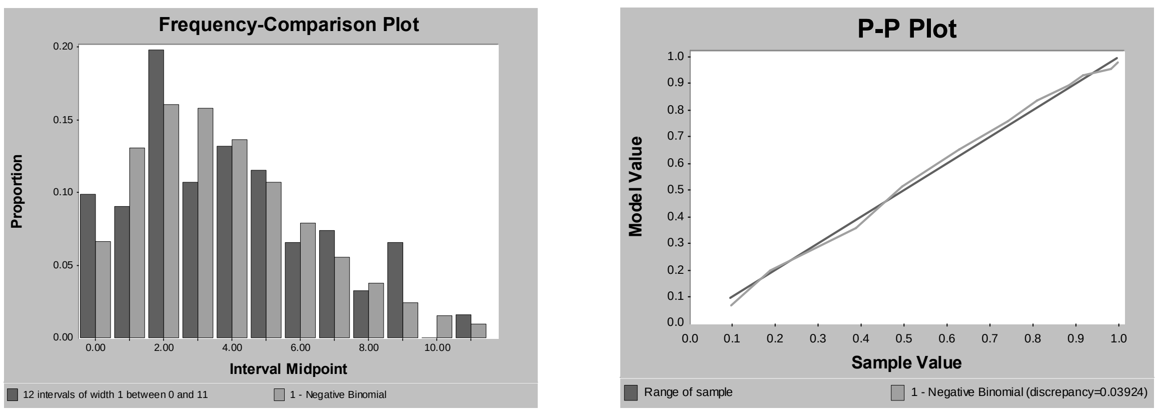


Figure 4-18: Frequency-Comparison Plot and P-P Plot, Direct Admit to Medical Program

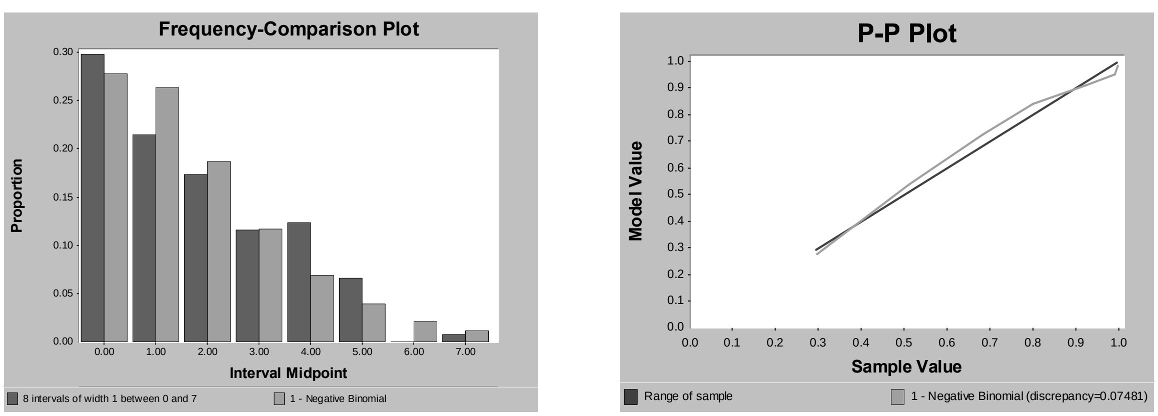


Figure 4-19: Frequency-Comparison Plot and P-P Plot, Direct Admit to Oncology

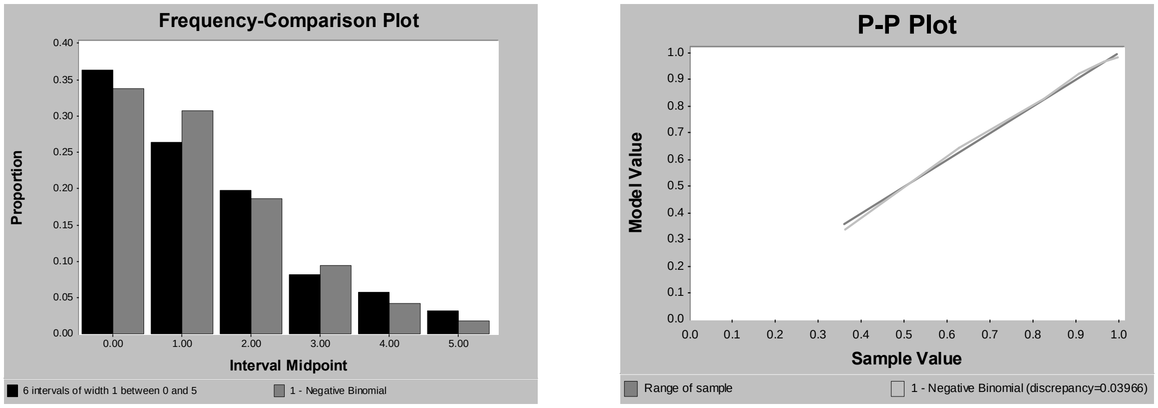


Figure 4-20: Frequency-Comparison Plot and P-P Plot, Direct Admit to Paediatrics

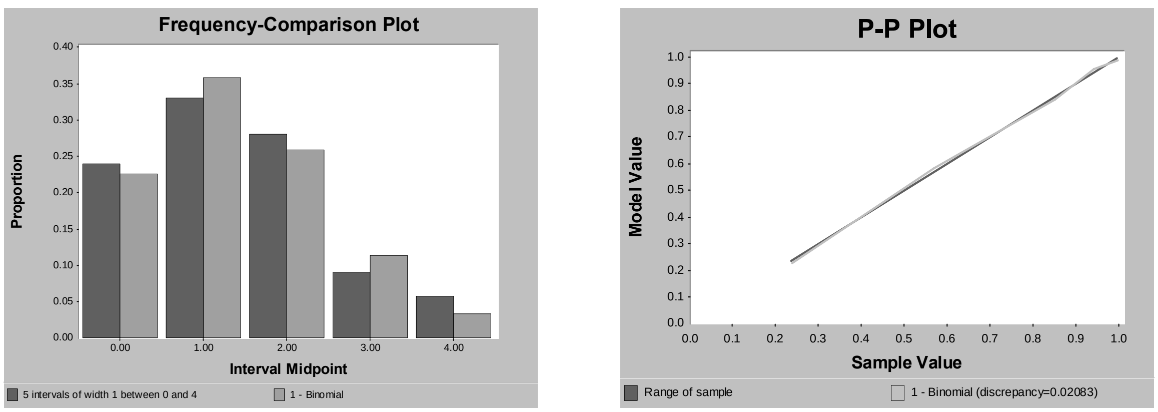


Figure 4-21: Frequency-Comparison Plot and P-P Plot, Emergency Admit to CCU

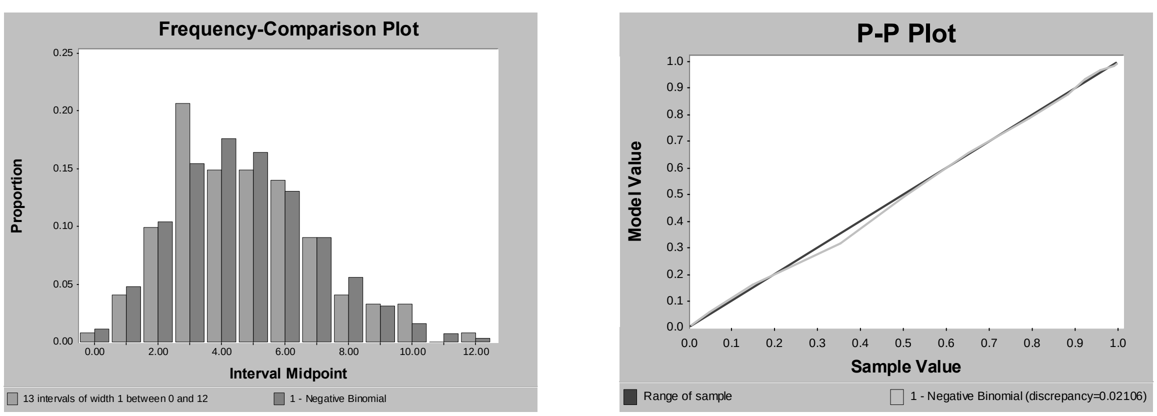


Figure 4-22: Frequency-Comparison Plot and P-P Plot, Emergency Admit to General Surgery

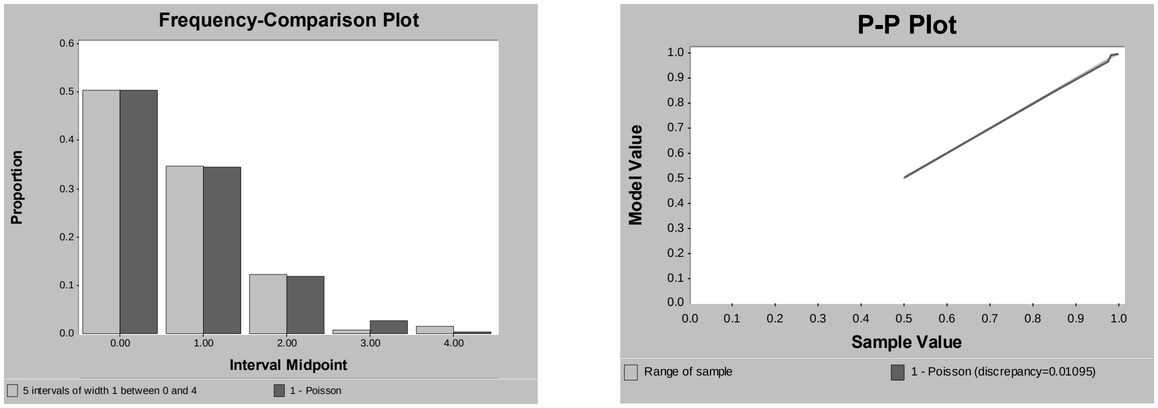


Figure 4-23: Frequency-Comparison Plot and P-P Plot, Emergency Admit to ICU

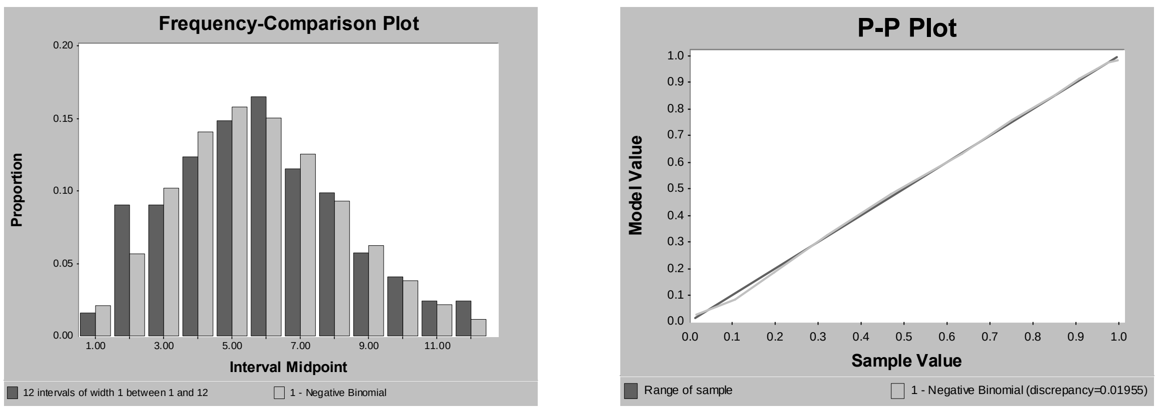


Figure 4-24: Frequency-Comparison Plot and P-P Plot, Emergency Admit to Medical Program

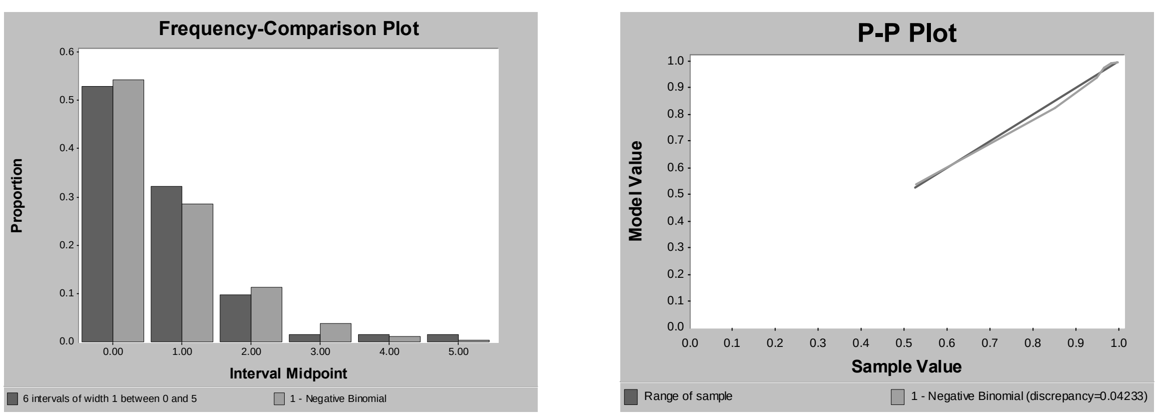
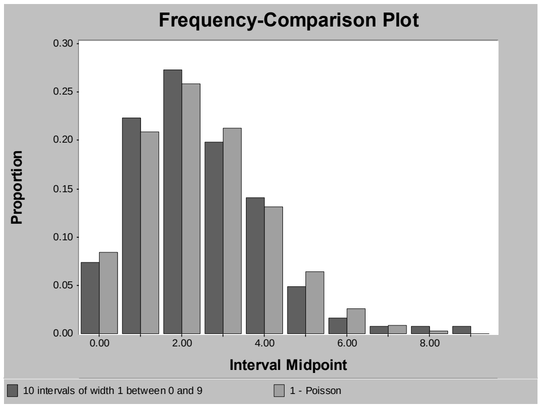


Figure 4-25: Frequency-Comparison Plot and P-P Plot, Emergency Admit to Oncology



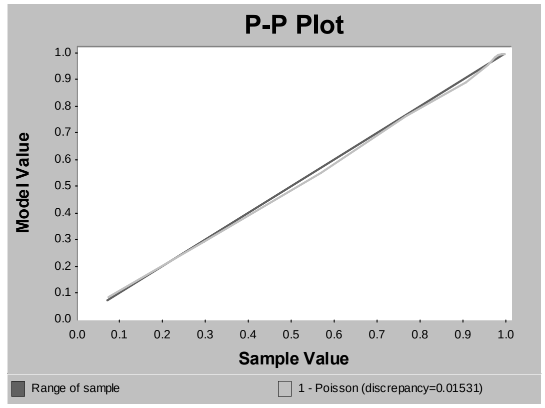
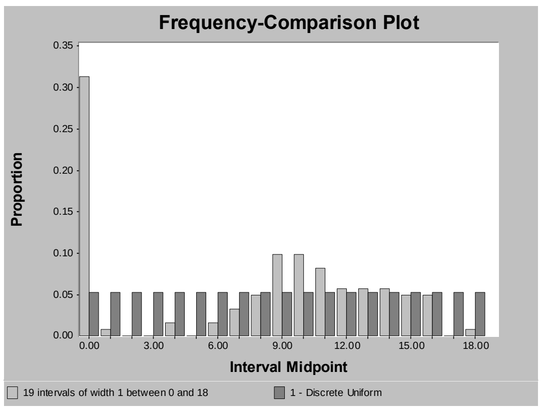


Figure 4-26: Frequency-Comparison Plot and P-P Plot, Emergency Admit to Paediatrics



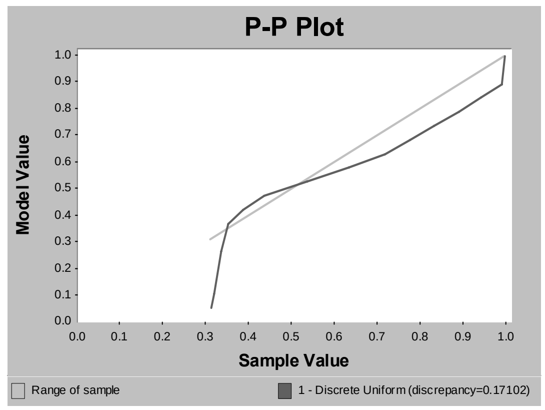
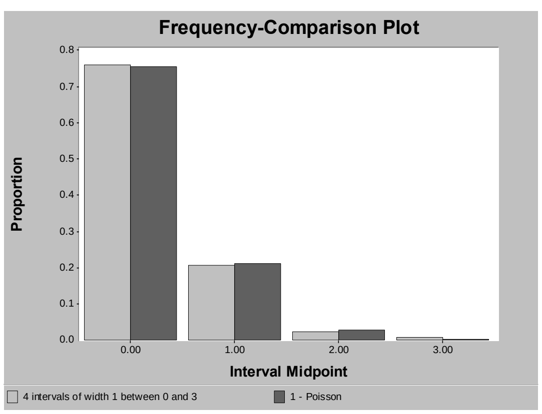


Figure 4-27: Frequency-Comparison Plot and P-P Plot, Day Surgery Admit to General Surgery



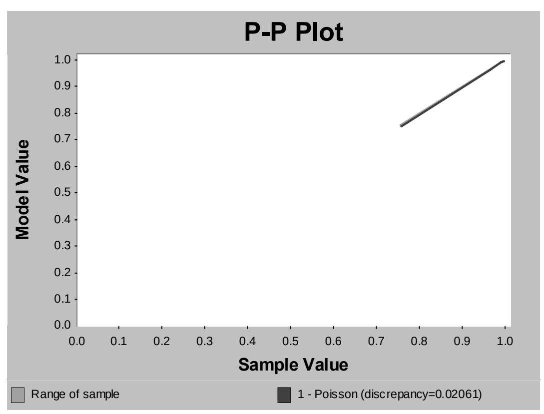
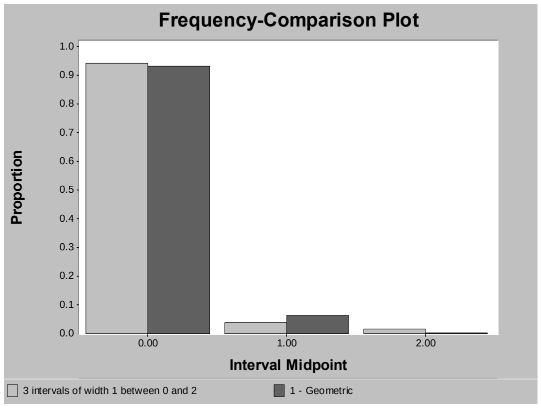


Figure 4-28: Frequency-Comparison Plot and P-P Plot, Day Surgery Admit to ICU



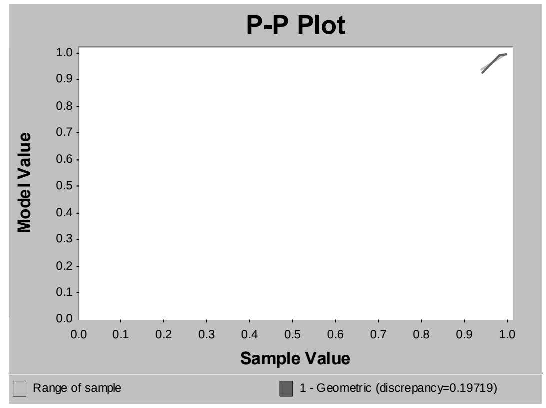


Figure 4-29: Frequency-Comparison Plot and P-P Plot, Day Surgery Admit to Paediatrics

4.4 Simulation Model Development

In order to operationalize the simulation model, Simul8, which is a user-friendly simulation package, was selected. One of the reasons to choose this software was its ease of use along with its robust modeling options and features compared to simulation programming languages. Comparisons of different simulation packages can be found in OR/MS Today (Swain, 2005). Constructing the simulation model was primarily done using Simul8 built-in features.

In the simulation model, all departments used a single supply of pumps. At the beginning of each day, the number of patients to be released from each department was determined. The pumps that were attached to these patients became free, but these pumps were not yet returned to the main supply. At the same time, the number of patients admitted into each department, their length of stay, and their pump requirements were determined according to the respective input probability distributions (see Section 4.3.1). The department then used the released patients' freed up pumps for the new patients and acquired the rest of their requirements, if necessary, from the main supply. If the freed up pumps were more than the new patients' pumps required, the extra pumps were returned to the main supply. In order to avoid blocking the simulation run, no limitation was considered for the number of pumps available in the main supply. However, total number of available pumps in the actual system (224 pumps) was sufficient to satisfy the demand of all departments.

The final results of each simulation run yielded the number of pumps used in each department on each day, during a one year period, when department's needs were unconstrained. The number of pumps short or in excess in each department, and the time spent to fulfill the demand for pumps in the current system, and in the suggested pump management systems were calculated using these results. These calculations will be thoroughly explained in Chapter 6. The logic of the daily flow of pumps and patients applied by the simulation model is presented in Figure 4-30.

With this information, one can determine distribution of total pumps required on a daily basis, by department and for the hospital as a whole. This can be used to assess:

1. The number of pumps required for the entire hospital to meet any specified service level (assuming that there is one pool of shared pumps).

2. The number of times there would have been a shortage, or there would have been an excess of pumps in the current system.

This then forms the basis of subsequent comparisons of pooled pump inventories versus no pooling.

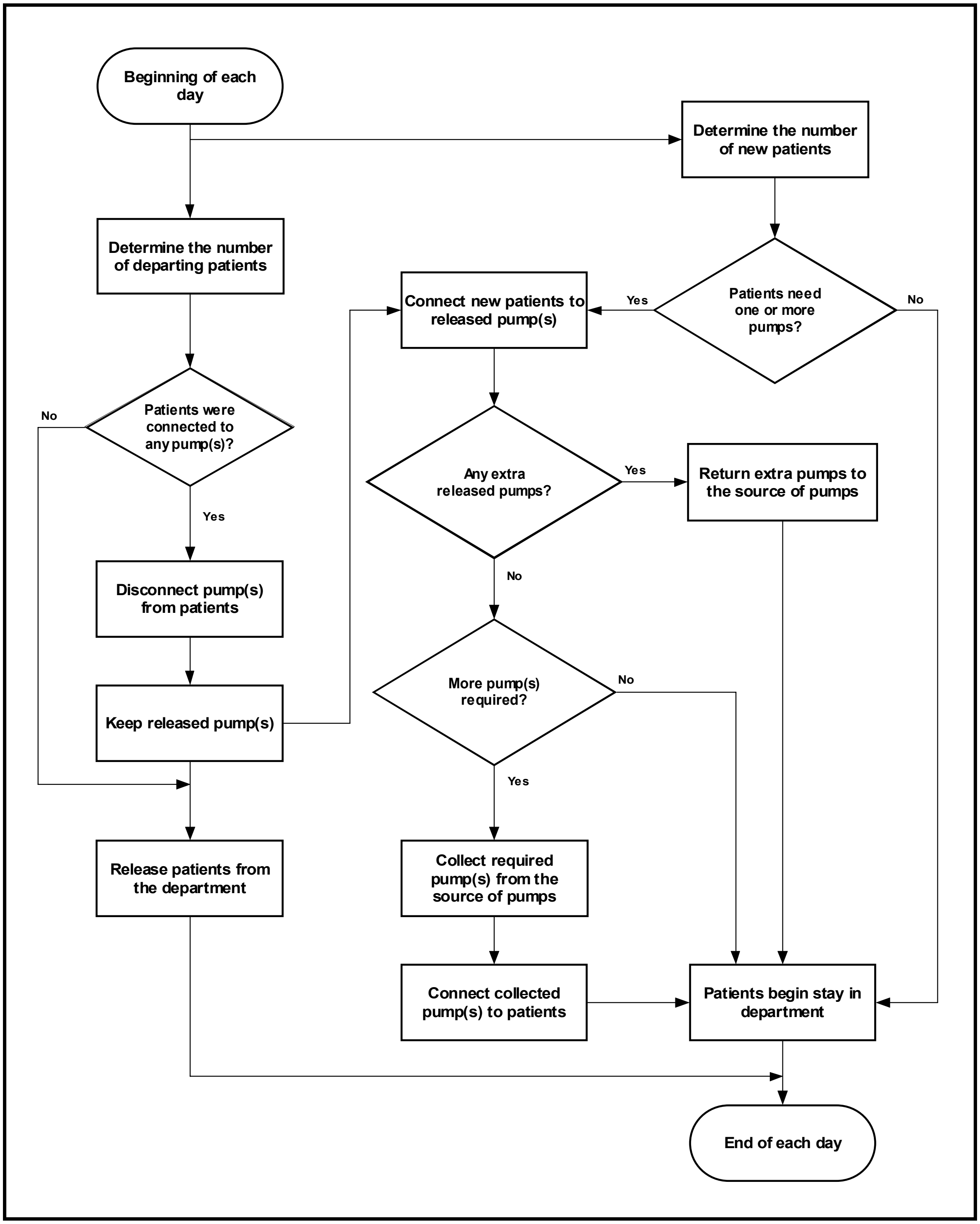


Figure 4-30: Daily Flow of Pumps and Patients in the Simulation Model, by Department

Figure 4-31 shows a screen shot of the model at time zero in Simul8 setting. This figure resembles Figure 4-3, which is the representation of the current system. The clock runs on a daily basis, therefore, the number of patients admitted in a department in each simulation time unit is the sum of patients admitted into that department in one day. Each department is shown with a bed icon. The capacity of each department (number of beds) is the “replication” of that department in the simulation model. Table 4-4 shows the number of beds in each department. Arrows represent the patient flow in-between departments. Table 4-5 shows the percentages of patients in every department who move to other departments or are discharged from the hospital.

Table 4-4: Number of Beds in Each Department

Department	No. of Beds
CCU	9
General Surgery	76
ICU	12
Medical Program	86
Oncology	24
Paediatrics	18

Table 4-5: Percentages of Patients Released from Each Department

To \ From	CCU	General Surgery	ICU	Medical Program	Oncology	Paediatrics
CCU		1%	13%	2%	0%	0%
General Surgery	9%		31%	4%	0%	0%
ICU	4%	3%		2%	4%	0%
Medical Program	45%	3%	20%		2%	0%
Oncology	2%	1%	4%	3%		0%
Paediatrics	0%	0%	0%	0%	0%	
Discharge	40%	92%	32%	89%	94%	100%
Total	100%	100%	100%	100%	100%	100%

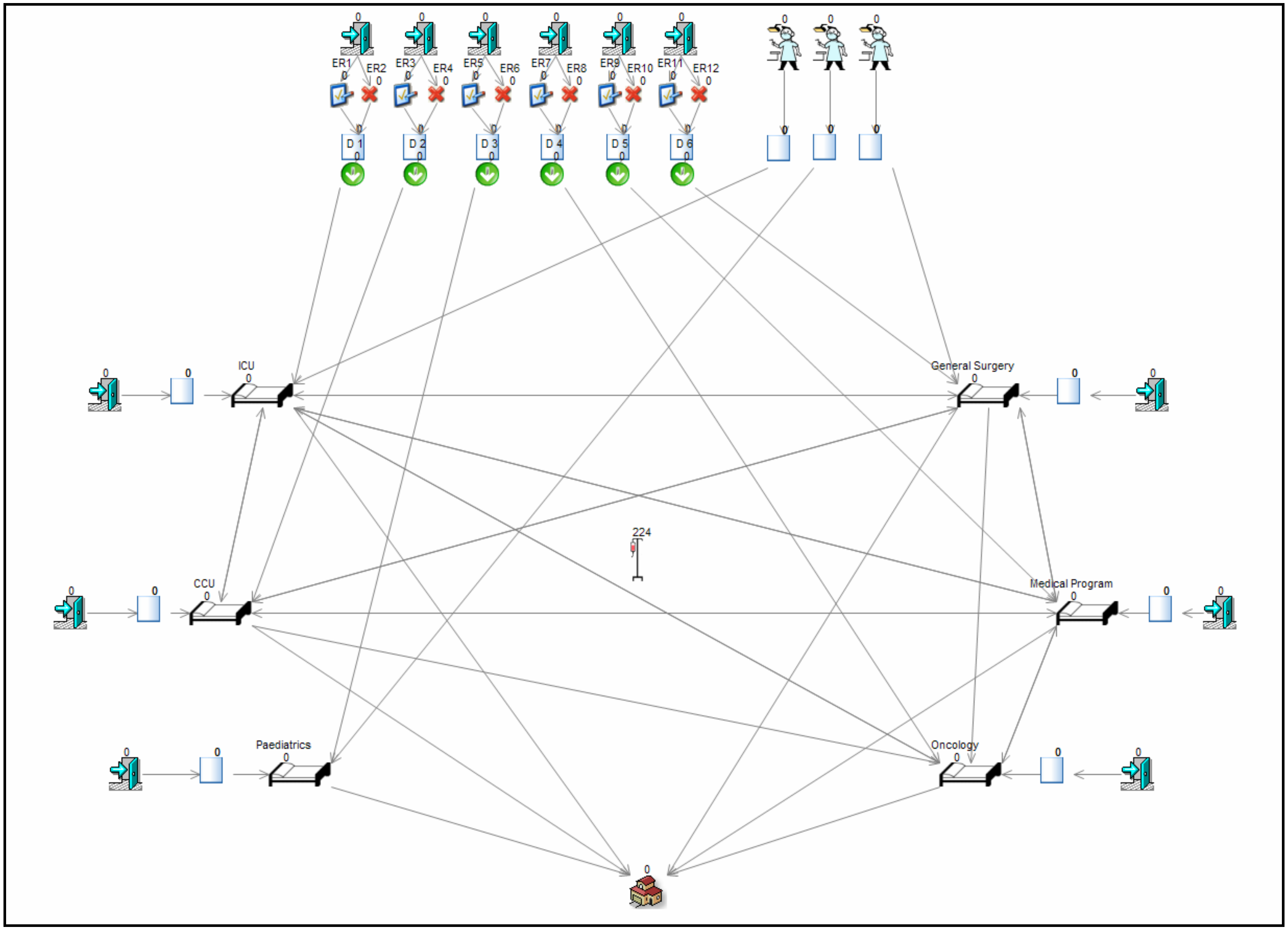


Figure 4-31: Simulation Model Screen Shot at Time Zero in Simul8 Setting

4.5 Assumptions

Due to the complications of real systems, simulation models are not an exact duplication. Assumptions are usually made to firstly, bound the model to a specific condition (data assumptions), and secondly, simplify the model to show an abstraction of reality that is solvable (structural assumptions). The following are a combination of both types of assumptions that were made during the construction of the simulation model:

- The simulation time unit is one "day." This assumption is consistent with the purpose of the model, which is to obtain overall measures of the daily number of pumps in use in each of the departments. The variability in input data was captured by the probability distributions that were based on the actual data. However, the distributions produce input data points independent from one another and in a random order during a one year period. Therefore, the impact of correlated data resulting from heavy demand periods, e.g. the first long weekend in winter that increases the rate of fractures, is not taken into consideration. Correlated demand patterns may affect the overall results of the simulation, and can be studied in future research.
- Each week consists of 7 days. The system works 7 days a week with no interruptions. This is similar to the actual situation in the hospital.

- Departments admit patients on a “first come, first serve,” basis. The capacity of the departments is sufficient to meet the demand; however, in case a department is running at a 100% occupancy rate and other patients need to move into that department, if the patients are already in the hospital, they stay in their current unit until a bed becomes available in the intended department. If the patients are direct admits, they may need to wait a short time for a bed to become free. In the actual system, patient admission is based on both patients’ turns and their critical condition. If a person needs immediate care, he or she is admitted to the hospital. However, this will not affect the outcome of this simulation model since the study is looking at the problem in an aggregate level and the overall number of patients admitted into each department remains the same.
- All patient movements in one day happen during one unit of simulation time; therefore, all discharges, transfers and admission occur at the beginning of a day. This is a reasonable assumption considering the aggregate level of the simulation model.
- The distance between the departments is assumed to be 0 since all the transfers take place in less than one simulation time unit. At this point, the simulation yields the cumulative number of pumps in use during one day. The time to retrieve each pump, which is a function of the distance between departments, is estimated from the results of the simulation.
- The time to prepare the used bed or used equipment for the next utilization is ignored since all of these tasks are done in less than one simulation time unit. The objective of the simulation model is to find the daily number of pumps required in each department. Overall, this assumption will not affect the daily number of pumps in use in a department.

- All admission probability distributions are based on actual data of the same 121 days, and are independent of one another. The method of obtaining these probability distributions is described in detail in Section 4.3.1.
- The number of days that each patient stays in a department is derived from the "Length of Stay" probability distributions related to each department.
- The number of pumps attached to each patient is derived from the "Pump Requirement" distributions related to each department.
- Pumps do not break during the utilization. However, 4 pumps are constantly out of use to represent the number of pumps that may break in the actual system, or may be in annual maintenance process. Based on this assumption, the impact of out of order pumps is taken into consideration in order for the simulation model to closely mimic the actual circumstances.
- Patients who need one or more pumps are attached to their required pump(s) during their entire stay in the department. This is one of the shortcomings of the simulation model. In reality, the number of pumps attached to a patient is reduced as the time passes and the patient heals. This could not directly be captured in this simulation model and the total number of pumps in use might slightly be overestimated. However, even with this overestimation, the outcome of the simulation showed that the actual number of pumps required in the system is fewer than the total number of pumps currently available in the hospital. This conclusion supports the fact that the hospital requires a more systematic pump management strategy.
- 80% of patients transferred to departments from the Emergency are attached to one infusion pump. Patients who are transferred between six departments of the study are first detached from a pump and then relocated. This assumption closely reflects the actual circumstances.

- Patients who are discharged from any of the departments exit the system. This assumption is in accordance with the actual situation.

4.6 Model Verification

"Verification is concerned with building the model correctly. It proceeds by the comparisons of the conceptual model to the computer representation that implements that conception (Banks et al., 2005)." In other words, verification is to check whether the computer program performs as it is supposed to. Different techniques are suggested in the literature for verification of computer programs. The following techniques were employed for verification purpose:

- A simulation package was used to reduce the required number of lines of code. Using built-in features of Simul8 helped minimize the number of probable errors occurring during construction of the simulation model.
- The model was run under simplifying assumptions, for which the model's true characteristics were known and easily computable.
- The simulation model was run under a variety of setups of input parameters, and the output was closely examined to make sure it was consistent with the input and yielded reasonable results.
- The animation of the simulation output was observed to assure that the flow imitated the actual system.
- The simulation was monitored as it progressed. It was temporarily paused after each unit of time to view model components such as patients, departments' conditions, and resources.
- The simulation was advanced until a specific time, and then suspended to display model information at that time. The information was inspected to confirm that the program was running as desired.

4.7 Model Validation

"Validation is concerned with building the correct model. It attempts to confirm that a model is an accurate representation of the real system (Banks et al., 2005)." Decisions are often made based on the model output; therefore, model's validity and credibility should be of great importance to model developers. Validation is a procedure that should be performed during model development process. The following steps, originally offered by Naylor and Finger (1967), were followed to validate the simulation model:

1. Face Validity: The purpose of this step is to create a model that seems reasonable to people who are knowledgeable of the studied system. One method to reach face validity is to obtain the information on the system from the people who are closely familiar with it. This study benefits from the support of clinical directors and other experts in the field who provided valuable information about the actual system. Another method to attain face validity is to observe the actual system. In fact, it is an advantage to obtain the data from historical records of an existing system. This was the case for this study.

2. Validation of Model Assumptions: The goal of this step is to examine the assumptions that were made during model development. There are different techniques to reach this goal. When a theoretical probability distribution is fitted to the actual data, it is possible to assess the adequacy of the fit by goodness-of-fit tests and graphical comparisons. Both of these methods were applied in this study to evaluate how well the input probability distributions represented the actual data. Details of this process were discussed earlier in "Input Data Analysis" section of this chapter. Another technique to validate model assumptions is sensitivity analysis. This technique measures to what extent the output differs, when the value or probability of an input parameter is changed. Sensitivity analysis was applied during the model development process. The parameters to which the output was sensitive were identified and carefully modeled.

3. Validating Input-Output Transformations: In general, a model accepts input parameters and transforms them into output performance measures. Validating input-output transformation is in fact verifying how closely the output data of the model resembles the output data expected from the actual system. For this purpose, a separate data set from the one that has been used to acquire the input probability distributions should be utilized. If the two outputs from the two data sets compare closely, the model is considered accurate, and therefore, valid. In this study, a recent data set was used to obtain input probability distributions for the simulation model, and the results were compared to output produced by the actual system during former years. In addition, the results of the empirical distributions were compared to the information provided by the experts about the actual system. These comparisons, which confirm the validity of the simulation model, are presented in the following tables.

Table 4-6: Total Number of Patients Served in Each Department in One Year

Department	Actual Data Fiscal Year 2004-2005	Data Produced by Simulation Model (Ave. of 10 Runs)
CCU	992	1053
General Surgery	7005	7497
ICU	747	948
Medical Program	4681	4353
Oncology	834	1277
Paediatrics	1409	1405
Total	15668	16533

Table 4-7: Average Occupancy Rate of Each Department in One Year

Department	Occupancy Rate Fiscal Year 2003-2004	Occupancy Rate Fiscal Year 2004-2005	Occupancy Rate Produced by Simulation Model (Ave. of 10 Runs)
CCU	68%	75%	80%
General Surgery	81%	82%	89%
ICU	73%	80%	76%
Medical Program	85.5%	87%	90%
Oncology	83%	82%	86%
Paediatrics	74%	72%	78%

Table 4-8: Average Number of Pumps in Use in Each Department

Department	Ave. No. of Pumps in Use Experts' Opinion	Ave. No. of Pumps in Use Produced by Simulation Model (Ave. of 10 Runs)
CCU	15	16.5
General Surgery	36	38.9
ICU	35	35.1
Medical Program	14	14.5
Oncology	20	20.0
Paediatrics	15	16.8

Table 4-9: Cumulative Inpatient Days of the Six Departments in One Year

Inpatient Days Fiscal year 2003-2004	Inpatient Days Fiscal year 2004-2005	Inpatient Days Produced by Simulation Model (Ave. of 10 Runs)
59068	66332	65580

Table 4-6 shows the total number of patients completed their stay in each department during one year. The first column represents the name of the departments. The second column shows the actual data set from the fiscal year 2004-05. The last column shows the number of patients completed their stay in each of the departments during one year. This number is the average results of 10 runs of the simulation model. The numbers in the last column are produced by the simulation model and are reflecting the actual data that was used as input to the simulation model. Although these numbers are slightly higher than the actual data set from the fiscal year 2004-2005, they are a good representation of the number of patients who completed their stay in different departments during the fiscal year 2005-2006. For instance, the actual number of patients who were treated in the Oncology Department during the fiscal year 2005-2006 was in fact over 1,100.

This should be noted that the total number of patients discharged from the hospital (14073 patients, average of 10 runs) is different from the number presented in the last column of Table 4-6. This is due to the fact that a number of patients visit more than one department during their stay in the hospital and they are counted separately as occupants of each of those departments.

Table 4-7 illustrates the average occupancy rate of each department in one year. The occupancy rates of former years were acquired from the hospital records. The occupancy rate from the simulation model was obtained by dividing the average number of engaged beds of each department during one year by the total number of beds in that department. In general, the occupancy rates produced by the simulation model are slightly more than the rates in the previous years; however, these numbers are accurately reflecting the actual situation as approved by the clinical directors. Appendix C consists of diagrams showing the daily number of engaged beds, or in other words, the daily occupancy of each department.

Table 4-8 presents the average number of pumps in use in each department. This figure was not recorded in any document; however, the average number of pumps in use in each department was suggested by the department's clinical director according to his or her observation and experience. The average number of pumps in use calculated by the simulation model was derived from the average of 10 runs.

Table 4-9 demonstrates the total number of inpatient days for all six departments in the study during one year. The first two columns of the table were obtained from the hospital records. The value presented in the last column was obtained from the simulation output. This value is the result of multiplying the average of total number of patients discharged (14073 patients) by the average length of stay of each patient in the system (4.66 days), in 10 runs. The actual inpatient days in fiscal year 2004-2005 is only 1% different from the number of inpatient days produced by the simulation model. This, once again, reflects the validation of the simulation model.

4.8 Summary

This chapter discussed the details of patients and pumps flow, and the development of the simulation model, which reflected the current system. The objective of the model was to find the distribution of pump requirement of each of the departments in order to determine a safety measure for available pumps that ensures a certain service level. Data collection and input data analysis were thoroughly explained, and the simulation model, which was developed in Simul8 environment, was described. The last two concepts that were discussed in this chapter were verification and validation of the model. Verification ensured that the computer program performed as desired, and validation confirmed that the model was an accurate representation of the actual system.

Chapter 5: Design of Production Runs

This chapter explains the design of production runs of the simulation model. The primary and secondary performance measures are introduced and the conditions under which the simulation is run are discussed. The conditions to consider are: the length of the warm-up period, the length of the simulation runs and the number of replications to be made of each independent simulation run.

5.1 Introduction

The options available in a simulation experimental design and analysis depend on the type of simulation being considered. Simulations can either be terminating (transient), or non-terminating (steady-state) (Law & Kelton, 1991). "A terminating simulation is one that runs for some duration of time T_E, where E is a specified event (or set of events) that stops the simulation. Such a simulation starts at time 0 under well-specified initial conditions and closes at the stopping time T_E (Banks et al., 2005)." "A non-terminating simulation is one for which there is no natural event E to specify the length of a run (Law & Kelton, 1991)." These simulations are usually referred to as "steady-state" simulations. The simulation model in this study is a non-terminating simulation. The objective of this thesis is to study the long-run or steady-state behaviour of the simulation model described in Chapter 4.

In order to study the output from any simulation, decisions ought to be made regarding the initial conditions for the simulation runs, the length of the warm-up period, the length of the simulation runs, and the number of replications to be made of each independent simulation run. These decisions have a major impact on the simulation output data, and consequently may have a large impact on the decisions that are made from the analysis.

5.2 Performance Measures

Performance measures are measures characterizing the behaviour of a system by which the system can be assessed. A system may have many different performance measures, depending on what objectives the analyst has. The objective of studying this system is to provide guidance to the hospital staff on the impact of alternative pump management methods. To achieve this objective, the primary performance measures are:

- The total number of pumps in use per day, in the hospital (*Y*). This measure shows the sum of daily number of pumps in use by each department and is used for calculations related to the initial conditions, under which the simulation is run.
- The daily number of pumps in use, by department (*P*). This measure provides a better understanding of each department's daily pumps in use that consists of the pumps already attached to patients when admitted in a department (from the Emergency Department), the pumps that are already in use from the previous day, and the additional pumps that are required for admitted patients per day.
- The daily number of pumps short, by department (*S*). This measure presents the number of pump shortage that occurs daily in each department. The shortage occurs when the number of required pumps is more than the number of pumps available in that department. This measure is used to calculate the labour hours spent to retrieve pumps for patient care.
- The daily number of pumps in excess, by department (*E*). This measure shows the number of extra pumps in a department per day. The excess occurs when the number of freed up pumps from the released patients is more than the number of required pumps for the new admitted patients. This measure is used to calculate the labour hours spent to return extra pumps to a central location.

In addition to the primary performance measures, a number of secondary performance measures captured to further characterize the system behaviour. They are as follows:

- The daily number of occupied beds. This measure was used to assist with model validation. The number of occupied beds divided by the total number of beds in each department provides the daily occupancy rate of that department. The average result was compared to the actual average occupancy rates existing in the hospital records.
- The daily number of patients leaving each department. This measure was calculated for each department and was compared with actual records from previous years as part of the validation process.
- The total number of patients discharged from the hospital per day, and each patient's length of stay. Multiplying these two measures gives what the hospital staff refer to as "inpatient days". The simulated "inpatient days" was compared to the actual data from the previous years, once again, as part of the validation process.

5.3 The Initial Conditions

The purpose of every run of this study's non-terminating simulation model is to estimate the steady-state characteristics of the system. A single run produces daily observations of total pump use of Y_i, $i = 1,\ldots, n$. The steady-state (or long-run) measure of performance, θ, is defined by (Banks et al., 2005):

$$\theta = \lim_{n \to \infty} \frac{1}{n} \sum_{i=1}^{n} Y_i \tag{5.1}$$

The run length of the model, n, is determined by the analyst according to a number of considerations that will be discussed later. According to Banks et al. (2005), the point estimator of θ based on the output data $\{Y_1, \ldots, Y_n\}$ is defined by:

$$\hat{\theta} = \frac{1}{n}\sum_{i=1}^{n} Y_i \tag{5.2}$$

$\hat{\theta}$ is a sample mean based on a sample of size n. The point estimator $\hat{\theta}$ is said to be unbiased for θ if its expected value is equal to θ, that is:

$$E(\hat{\theta}) = \theta \tag{5.3}$$

However, in actual systems,

$$E(\hat{\theta}) \neq \theta \tag{5.4}$$

Therefore, $E(\hat{\theta}) - \theta$ is called the "bias" in the point estimator, $\hat{\theta}$. It is desirable to have estimators with no, or a small bias relative to the magnitude of θ.

There are numerous methods to reduce the point estimator bias that is caused by unrealistic initial conditions in a steady-state simulation. One method is to start the simulation in a state that is similar to the long-run conditions. However, this method may require a large amount of data collection. Another method is to divide each simulation run into two phases: An initial phase from time 0 to time T_0, where the system is allowed to reach steady state, and the data-collection phase from T_0 to the stopping time T_0+T_E. Defining T_0 is important, because the system condition at time T_0 should be a better representation of the steady-state behaviour of the system than is the original condition at time 0. Too small a T_0 may leave biased data in the data-collection phase, and too large a T_0 may disregard useful data in the analysis. In a simulation, the time between time 0 and T_0 is called the warm-up period.

To determine T_0, the following procedures were followed (Banks et al., 2005):

The first step was to produce r replications (runs) of the simulation. It is suggested by the literature to choose $r \geq 5$. This model was run several times and the result of each run was thoroughly examined. The mean of the average number of pumps in use in the system was 153.85, 153.73, and 153.66 if the simulation was run 10, 20, and 30 times respectively. The standard deviation of the average number of pumps in use in the system was 3.54, 3.18, and 3.03 for 10, 20, and 30 replications respectively. It was observed that more replications do not yield outcomes with high variations. From this assessment, it was concluded that 10 replications yielded reasonable results and adding more replications would only increase the volume of data without adding more value to the results.

The next step was to batch the output data within each individual run. Using trial and error, a variety of batch intervals were chosen. A batch size equal to 20 days was eventually chosen to provide a reasonable level of granularity in the results; therefore, each batch consisted of 20 observations of daily pump use. The length of each replication, T_E, was considered 380 days. T_E was sufficiently large to provide a reasonable estimate of the steady-state behaviour of the system (see Section 5.4). As a result, each replication consisted of 19 batches of data. The average of each batch was calculated (Y_{rj}). Y_{rj} is the j^{th} batch mean for replication r, where $j = 1,\ldots, 19$ and $r = 1,\ldots, 10$. The 19 batch means for the 10 replications are displayed in Table 5-1. Plots of all 10 replications can be found in Appendix D.

To identify the initialization bias, the average of batch means of each batch j, $j = 1,\ldots, 19$, was calculated across replications. These averages are known as "ensemble averages" (Banks et al., 2005). For each batch, the ensemble average across all 10 replication was calculated as the following:

$$\overline{Y}_{.j} = \frac{1}{R}\sum_{r=1}^{R} Y_{rj}, \quad R = 10\,;\, j = 1,\ldots,\, 19 \tag{5.5}$$

The ensemble averages are shown in the third column of Table 5-2, and are plotted on Figure 5-1. This figure shows the downward bias of the first batch mean. However, the remaining observations appear to vary around a common mean. Based on this, the data-collection period began after eliminating the initial point (containing 20 days).

The same conclusion was also obtained by applying the cumulative average sample mean technique (Banks et al., 2005) that eliminates zero, one, and two batch means from the beginning of the simulation. In other words, this method deletes d observations out of a total of n (n = 19) observations in calculating cumulative averages. The cumulative averages were calculated by the following:

$$\overline{Y}_{..(n,d)} = \frac{1}{n-d} \sum_{j=d+1}^{n} \overline{Y}_{.j}\ ,\ d = 0,\ 1,\ 2;\ n = 19;\ j = 1,\ \ldots,\ 19 \tag{5.6}$$

Table 5-2 summarizes the results of ensemble batch means and cumulative means, averaged over 10 replications, for d = 0, 1, and 2, and n = d + 1,…, 19. The cumulative average with no deletion of batch means, deletion of first batch mean, and deletion of the first two batch means are plotted in Figure 5-2. This figure also shows the initial bias due to the simulation warming up from its initially empty state. It appears that the first observation has considerably more bias than the remainder of the points. Therefore, the first batch was deleted and accordingly most of the bias was eliminated. The first batch represented the first 20 days of the simulation run and hence was considered as the warm-up period. Accordingly, the data of the first 20 days produced by the simulation were not taken into account for the purposes of output analysis. This was done to remove the initialization bias from the simulation output.

Table 5-1: Individual Batch Means for Simulation Model with Empty and Idle Initial State

Replication \ Batch	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	132.30	165.40	179.30	149.00	136.75	153.25	156.55	167.20	150.75	164.55	164.25	157.55	183.05	158.40	140.40	158.05	150.70	163.45	135.80
2	119.35	164.75	175.60	161.75	131.85	149.05	168.10	159.60	162.75	152.70	154.00	155.70	162.15	158.05	144.80	144.15	156.40	163.00	156.60
3	115.30	143.30	151.35	142.25	146.60	137.45	161.00	162.30	151.15	179.00	171.55	159.95	158.00	163.30	156.90	144.25	174.85	145.15	145.00
4	115.00	144.50	170.50	138.30	137.05	136.75	141.25	138.30	145.25	149.30	149.35	142.40	165.50	160.40	167.25	162.70	165.00	156.60	157.35
5	103.75	155.60	146.95	170.20	146.60	161.00	153.90	160.45	150.65	153.75	148.45	159.30	169.90	168.85	160.40	159.90	165.75	150.75	137.70
6	106.40	139.20	133.20	159.05	153.15	142.20	157.05	151.40	141.65	151.50	168.45	171.85	159.30	155.75	146.90	139.70	148.85	151.70	150.60
7	115.55	151.90	151.95	172.60	152.65	137.00	142.20	144.25	148.80	172.20	164.85	138.65	139.75	148.15	126.35	154.70	134.35	148.25	146.95
8	108.65	153.60	159.05	152.35	169.85	156.95	140.30	165.10	140.90	161.65	160.40	144.55	169.30	165.55	157.45	147.60	139.10	150.90	156.15
9	116.00	165.10	160.10	150.05	170.10	169.60	165.00	156.40	149.60	137.90	155.50	155.55	170.25	156.15	159.05	150.65	148.30	161.90	156.10
10	123.15	143.55	154.40	169.15	162.25	146.70	156.00	170.50	165.05	140.05	132.60	150.55	179.20	158.75	165.55	182.20	137.25	143.65	176.25

Table 5-2: Ensemble Batch Means and Cumulative Means, Averaged Over 10 Replications

Run Length (Days)	Batch	Average Batch Mean	Cumulative Average (No Deletion)	Cumulative Average (Delete 1)	Cumulative Average (Delete 2)
20	1	115.55	115.55		
40	2	152.69	134.12	152.69	
60	3	158.24	142.16	155.47	158.24
80	4	156.47	145.74	155.80	157.36
100	5	150.69	146.73	154.52	155.13
120	6	149.00	147.10	153.42	153.60
140	7	154.14	148.11	153.54	153.71
160	8	157.55	149.29	154.11	154.35
180	9	150.66	149.44	153.68	153.82
200	10	156.26	150.12	153.96	154.12
220	11	156.94	150.74	154.26	154.44
240	12	153.61	150.98	154.20	154.35
260	13	165.64	152.11	155.16	155.38
280	14	159.34	152.62	155.48	155.71
300	15	152.51	152.62	155.26	155.46
320	16	154.39	152.73	155.21	155.39
340	17	152.06	152.69	155.01	155.16
360	18	153.54	152.74	154.92	155.06
380	19	151.85	152.69	154.75	154.87

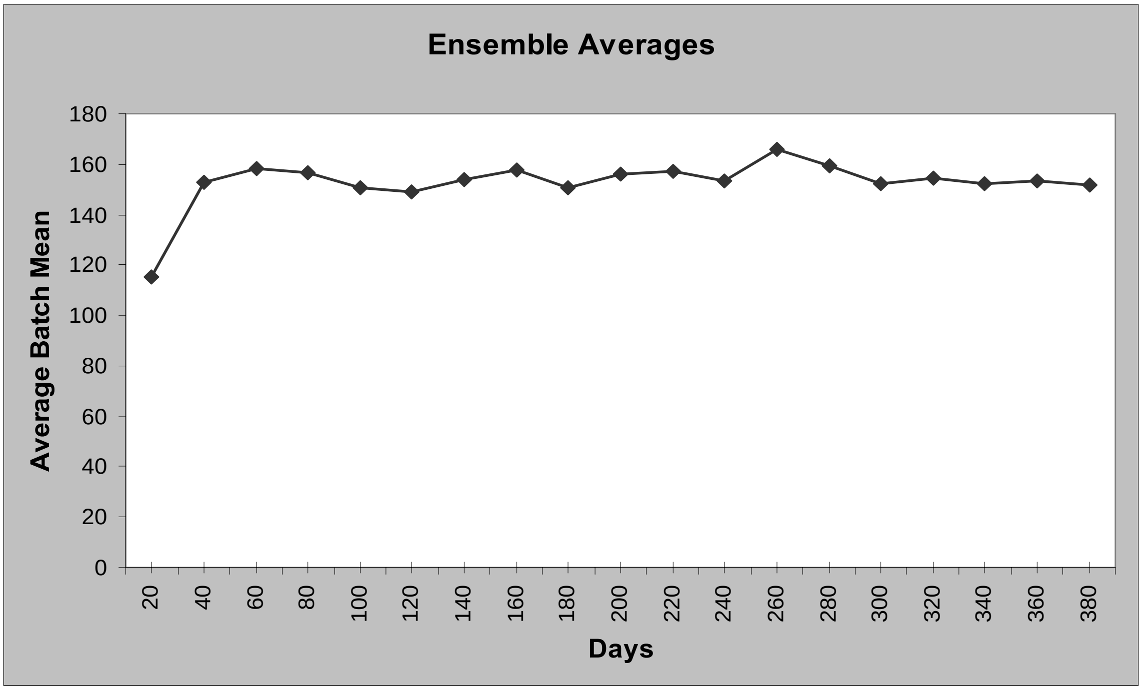


Figure 5-1: Ensemble Averages (19 Batches)

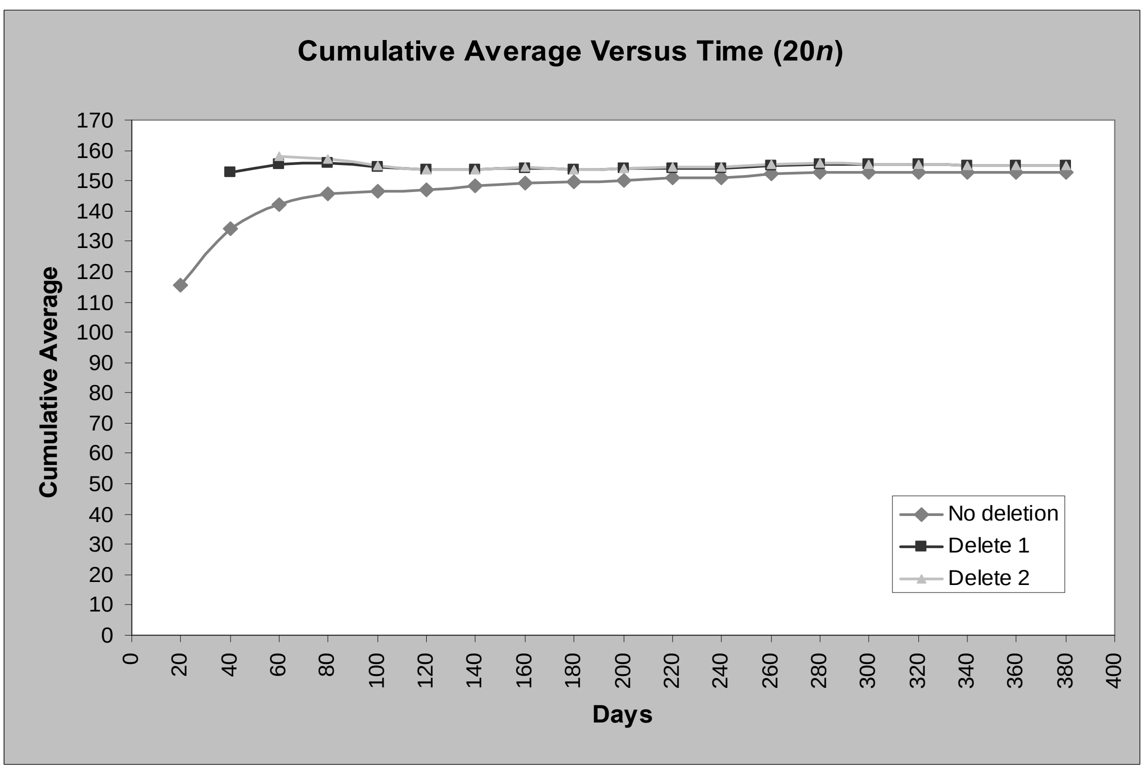


Figure 5-2: Cumulative Average versus Time (20 Days Multiplied by 19 Batches)

5.4 Simulation Run Length

According to Banks et al. (2005), the data-collection period for each simulation run should be at least ten times the length of the warm-up period. As discussed before, a 20 day warm-up period was used for this simulation. Based on Bank's recommendation, the length of each replication could be 200 days or more. Since the data from the hospital were analyzed over a complete fiscal year, it was decided to consider 365 days for the simulation run length. Also, since former years' data used for validation comparisons were on an annual basis, a one year output of the simulation was thought to be reasonable to produce results over the same time period. Therefore, every run of the simulation was 385 days consisting of a 20 day warm-up period, and a 365 day data-collection period.

5.5 Replication Method

According to Banks et al. (2005), the method of independent replications can be used to estimate the variability in the "point estimator" of a performance measure and to construct a confidence interval around the point estimate. Ten replications were carried out for the simulation (R = 10). Each replication was conducted using a separate and independent set of random numbers. The replications were used to construct a 95% confidence interval for the performance measure θ. In this method, each replication was assumed as a single sample for the purpose of estimating θ. The sample variance is calculated using the following equation:

$$S^2 = \frac{1}{R-1}\sum_{r=1}^{R}(\overline{Y}_{r.} - \overline{Y}_{..})^2 \tag{5.7}$$

Where $\overline{Y}_{r.}$ is the mean of the undeleted observations from the rth replication, and $\overline{Y}_{..}$ is the mean of $\overline{Y}_{1.},...,\overline{Y}_{R.}$. The standard error of $\overline{Y}_{..}$ is:

$$s.e.(\overline{Y}_{..}) = \frac{S}{\sqrt{R}} \tag{5.8}$$

A $100(1-\alpha)\%$ confidence interval for θ, based on the t distribution is:

$$\bar{Y}_{..} - t_{\alpha/2,R-1}\frac{S}{\sqrt{R}} \leq \theta \leq \bar{Y}_{..} + t_{\alpha/2,R-1}\frac{S}{\sqrt{R}} \tag{5.9}$$

Where $t_{\alpha/2,R-1}$ is the $100(1-\alpha/2)$ percentage point of a t distribution with R-1 degrees of freedom.

Table 5-3 summarizes the results obtained from the replication method. The middle column shows the replication sample mean of the data including the warm-up period observations. The rightmost column contains replication sample means of the data excluding the warm-up period observations. The sample variance and standard error of the results in both columns are also presented in the table.

Using $\alpha = 0.05$ and $t_{0.025,\,9} = 2.26$, the 95% confidence interval for the long-run average number of pumps in use is:

$$154.75 - 2.26\ (1.005) \leq \theta \leq 154.75 + 2.26\ (1.005)$$

Or: $$152.48 \leq \theta \leq 157.02$$

It can be concluded that the long-run average number of total pumps in use is between 152.48 and 157.02 pumps. If the simulation contained the data from the warm up period, the confidence interval would be:

$$152.69 - 2.26\ (1.010) \leq \theta \leq 152.69 + 2.26\ (1.010)$$

Or: $$150.41 \leq \theta \leq 154.97$$

Comparing the two confidence intervals indicates that including the warm-up period data in the calculations shifts down the confidence interval reflecting the downward bias in the initial observations.

Table 5-3: Data Summary for Simulation by Replication

	Sample Mean for Replication r	
Replication, *r*	$\overline{Y}_{r.}$ **(No Deletion)**	$\overline{Y}_{r.}$ **(Delete 1 batch)**
1	156.14	157.47
2	154.76	156.72
3	153.09	155.19
4	149.62	151.54
5	153.89	156.67
6	148.84	151.19
7	146.90	148.64
8	152.60	155.04
9	155.44	157.63
10	155.62	157.43
$\overline{Y}_{..}$	152.69	154.75
S^2	10.191	10.103
S	3.192	3.178
Standard Error of $\overline{Y}_{..}$	1.010	1.005

5.6 Summary

This chapter described the conditions under which each simulation run was made. First, the primary and secondary performance measures were introduced. One of the primary performance measures for the simulation is the number of pumps in use, by department, on a daily basis. This measure was used to determine a distribution for pump usage in every department of the hospital. Other primary performance measures are the number of pumps short and the number of pumps in excess per day that are used to study the current system and analyse alternative pump management methods.

Several decisions about the simulation conditions needed to be resolved in order for the output analysis to be valid. These are: the length of the warm-up period, the length of each simulation run, and the number of replications to be made of each independent simulation run. The length of the warm-up period was considered 20 days. The data produced by the simulation during this 20 day period were eliminated from the output results. The length of the data-collection period was considered 365 days (annual data analysis was conducted). Finally, the number of replications was considered 10.

Chapter 6: Output Data Analysis

This chapter presents the results of the experimental runs. The average number of pumps in use in each of the departments are quantified and presented in diagrams. The probability distribution of pump usage is also provided for each of the departments. Using these distributions, the number of pumps required to meet a specified service level can be determined. In addition to the pump usage information, the number of pumps short per day and the number of excess of pumps per day are quantified for every department.

In the second part of the chapter, the current pump usage situation is studied and the annual number of hours and the annual cost of labour to retrieve required pumps are calculated. The problem of pump management that caused long searches and frustration for the staff is examined, and two alternative pump management methods are suggested and also analysed.

1. The first alternative is to use a central pool of pumps. The annual number of labour hours and the annual cost of labour to retrieve required pumps are calculated for this method.

2. The second alternative is the use of RFID technology throughout the hospital. Aspects of this system are examined and the number of hours and the cost of labour to retrieve required pumps are calculated for this alternative.

The pump usage distribution for the centralized pooling system and the RFID system is also presented.

Finally, the current pump management system is compared with the two recommended alternatives, and the advantages and disadvantages of each of the central pooling system and the RFID technology are explained.

6.1 Results of Experimental Runs

The objective of output data analysis is to thoroughly examine the existing pump management situation, and to study alternative methodologies that may be able to improve upon current situation. As discussed in the previous chapter, 10 replications of the simulation model were run for output data collection and analysis. Data from the first 20 days of each replication is considered as the warm-up period and is not included in the output analysis.

Each replication simulated the daily number of pumps in use in each of the departments, for a one year period. This performance measure is shown by the symbol P_{kir}, where k is the index for the department (k = 1,…, 7; see Table 6-1), i is the period (i = 1,…, 365), and r is the replication (r = 1,…, 10). The daily number of pumps in use was the average of 10 data points for each day produced by 10 replications that yielded 365 point estimates for one year ($P_{ki.}$).

Table 6-1: Index of Each Department

Department	Index, *k*
CCU	1
General Surgery	2
ICU	3
Medical Program	4
Oncology	5
Paediatrics	6
Emergency	7

Figure 6-1 through Figure 6-6 are the visual representation of the daily number of pumps in use (average of 10 daily data points of 10 replications) in each of the six departments of the study. Table 6-2 shows the descriptive statistics of this performance measure. This table includes a one year period general observations of the mean, standard error, standard deviation, sample variance, and half-width of the 95% and 99% confidence interval of daily pump use in every department.

By looking at the sample variance of each of the departments separately, it can be seen that ICU and General Surgery have a larger variance than the other four departments. This suggests that the pump usage has more variability in these two departments. ICU holds fewer beds compared to General Surgery, though, it has the highest value of sample variance due to its wide range of pump use distribution. Therefore, the large sample variance of the General Surgery is due to its large number of beds (76 beds), and the large sample variance of the ICU is due to its wide range of pump use distribution.

The half-width of the 95% and 98% confidence intervals for all six departments are very small compared to the corresponding mean values. This means that we can be very confident that the actual pump usage is within a small range.

Table 6-2: Descriptive Statistics of No. of Pumps in Use by Department (One Year Period)

Department	Mean	Standard Error	Standard Deviation	Sample Variance	Confidence Interval (95.0%) Half-width	Confidence Interval (99.0%) Half-width
CCU	16.57	0.08	1.46	2.13	0.15	0.20
General Surgery	38.97	0.14	2.66	7.09	0.27	0.36
ICU	35.13	0.21	3.94	15.54	0.41	0.53
Medical Program	14.49	0.06	1.14	1.29	0.12	0.15
Oncology	20.03	0.06	1.19	1.42	0.12	0.16
Paediatrics	16.88	0.08	1.47	2.15	0.15	0.20

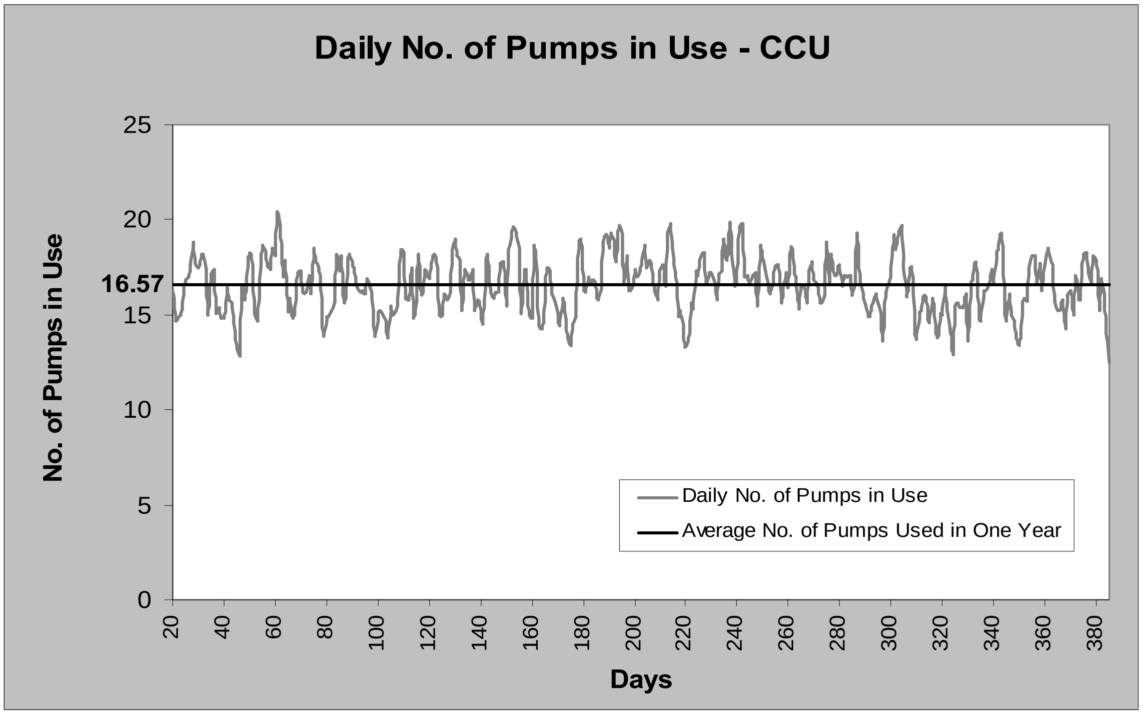


Figure 6-1: Daily No. of Pumps in Use - CCU

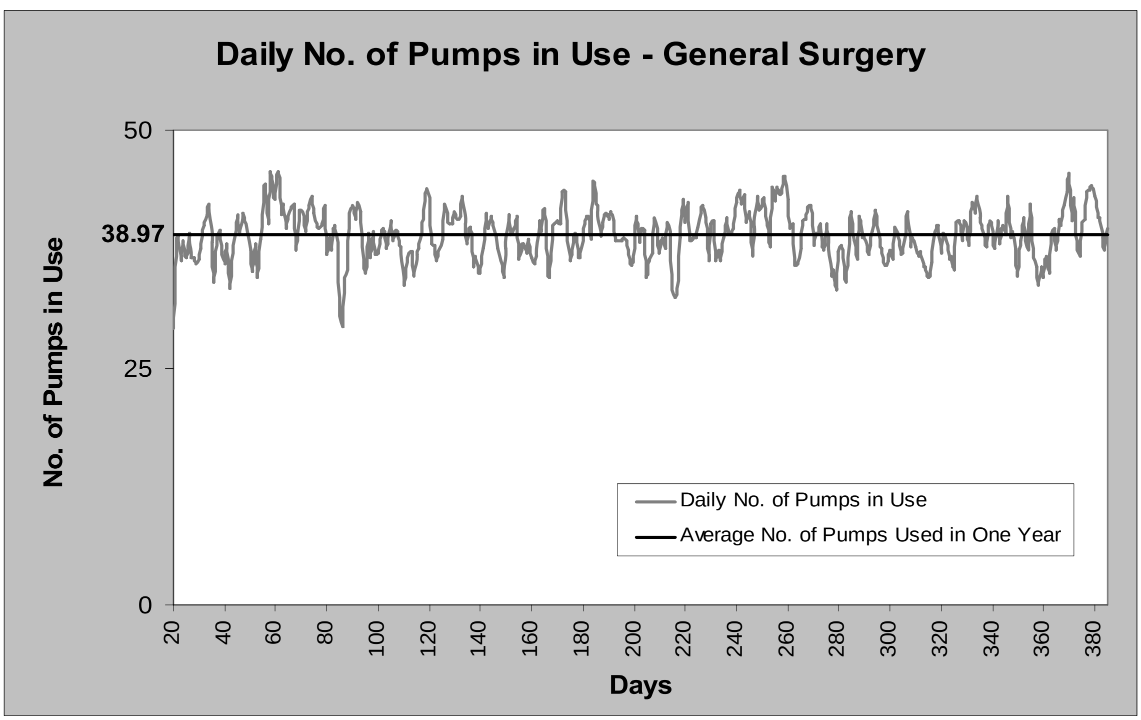


Figure 6-2: Daily No. of Pumps in Use - General Surgery

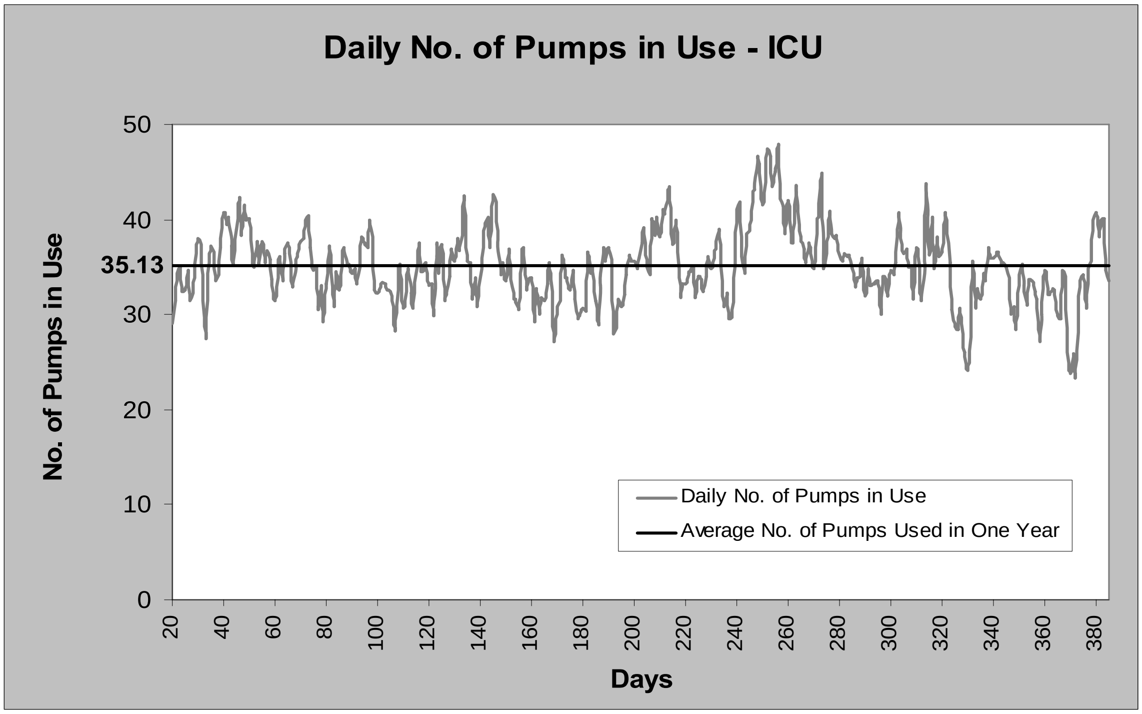


Figure 6-3: Daily No. of Pumps in Use - ICU

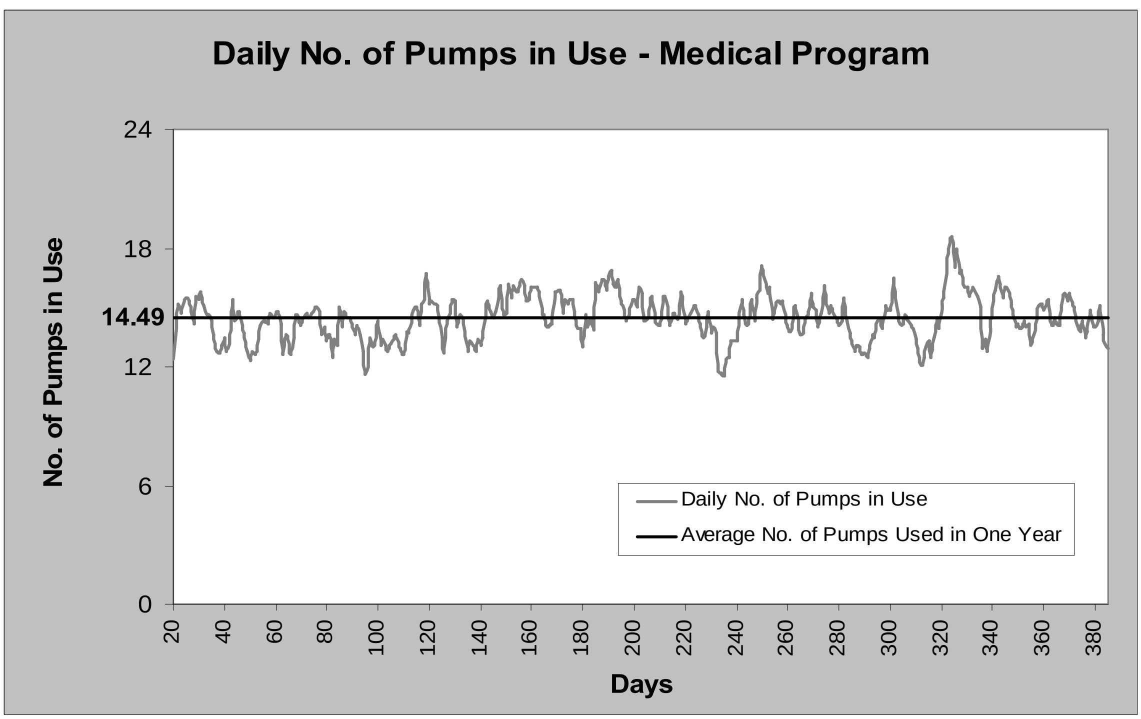


Figure 6-4: Daily No. of Pumps in Use - Medical Program

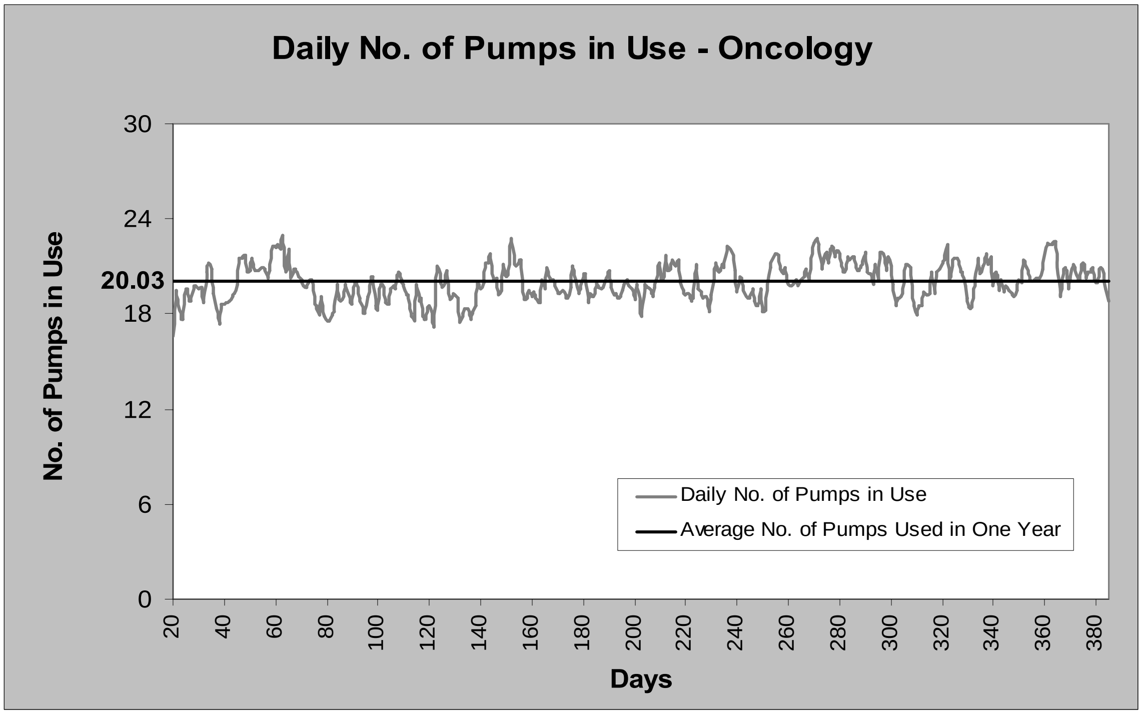


Figure 6-5: Daily No. of Pumps in Use - Oncology

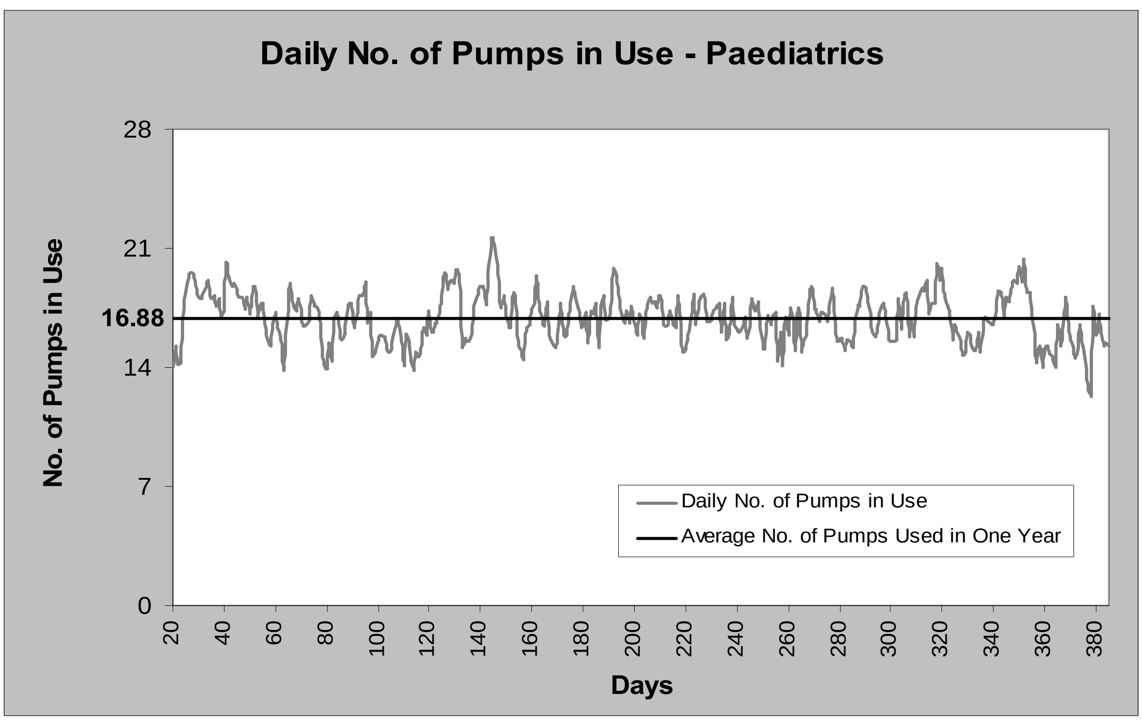


Figure 6-6: Daily No. of Pumps in Use – Paediatrics

6.1.1 Pump Use Distributions

To find the distribution of pump usage for each of the departments under study, the daily number of pumps in use that were produced by all 10 replications were pooled to construct histograms of the frequency of daily pump usage and the cumulative distribution of pump usage. The cumulative distributions were used to determine the number of pumps required to provide various service levels for each department. Figure 6-7 through Figure 6-12 present the pump usage distributions for the six departments.

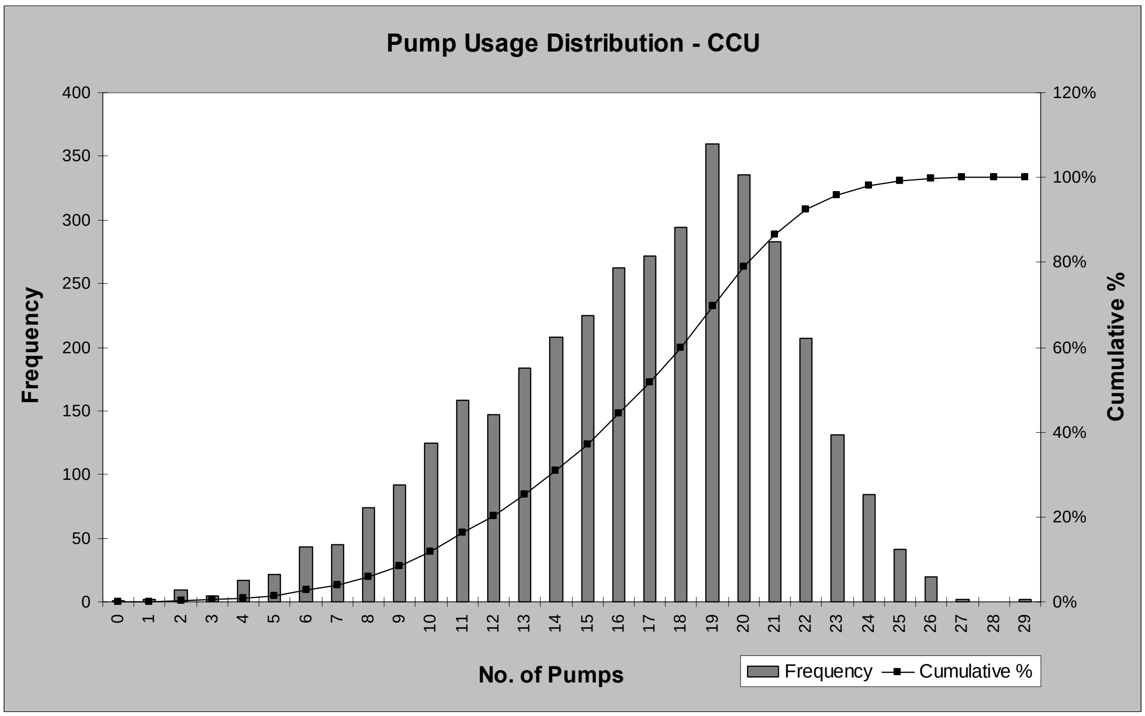


Figure 6-7: Pump Usage Distribution - CCU

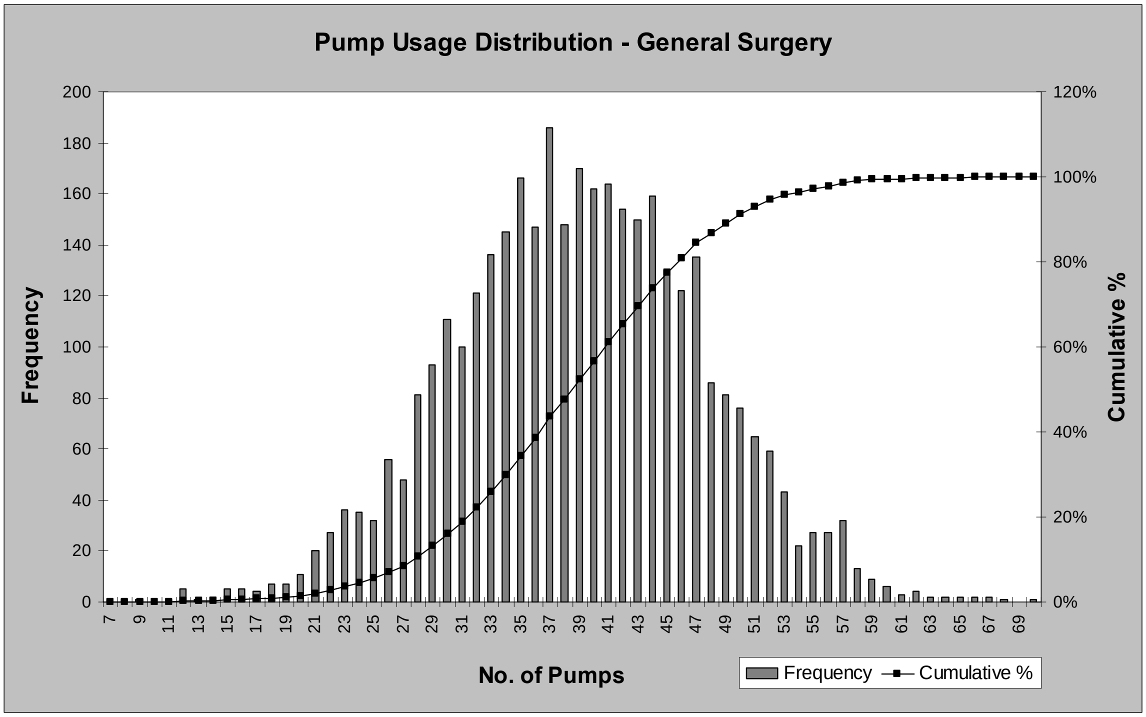


Figure 6-8: Pump Usage Distribution - General Surgery

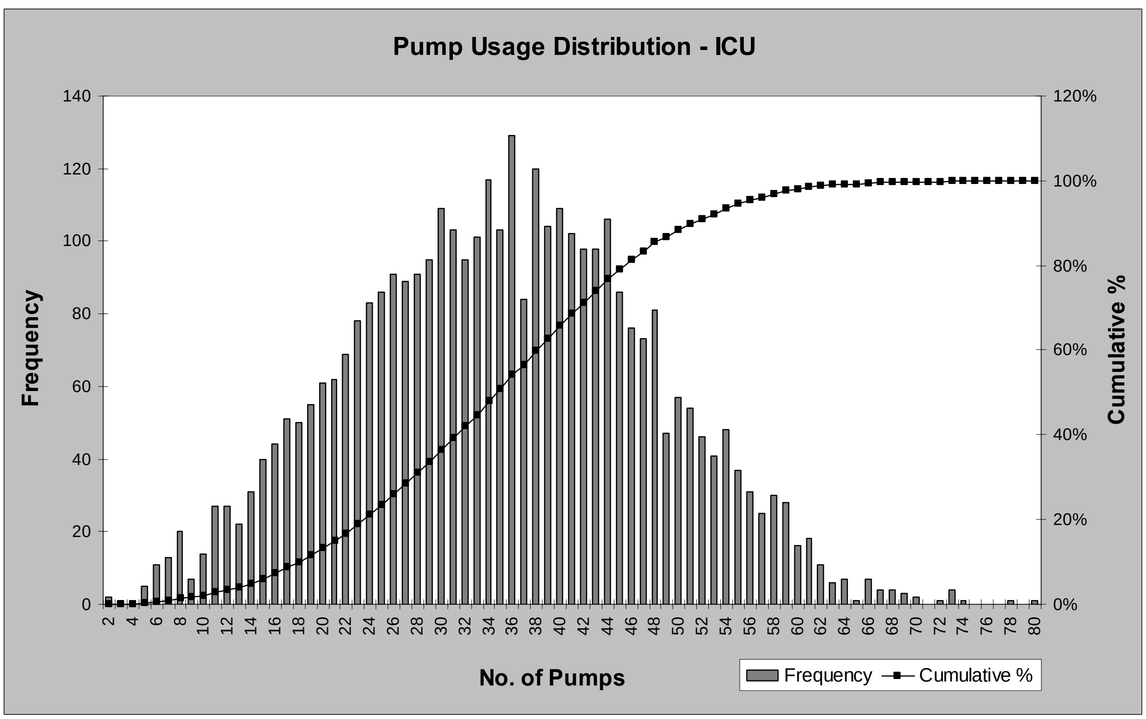


Figure 6-9: Pump Usage Distribution - ICU

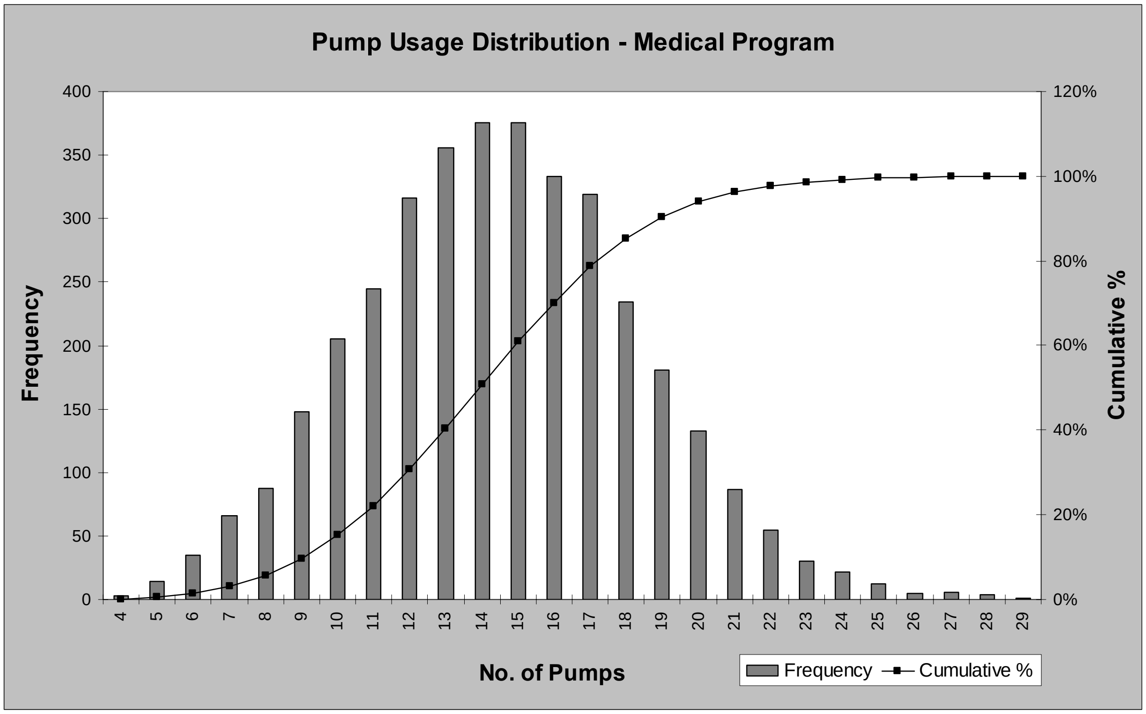


Figure 6-10: Pump Usage Distribution - Medical Program

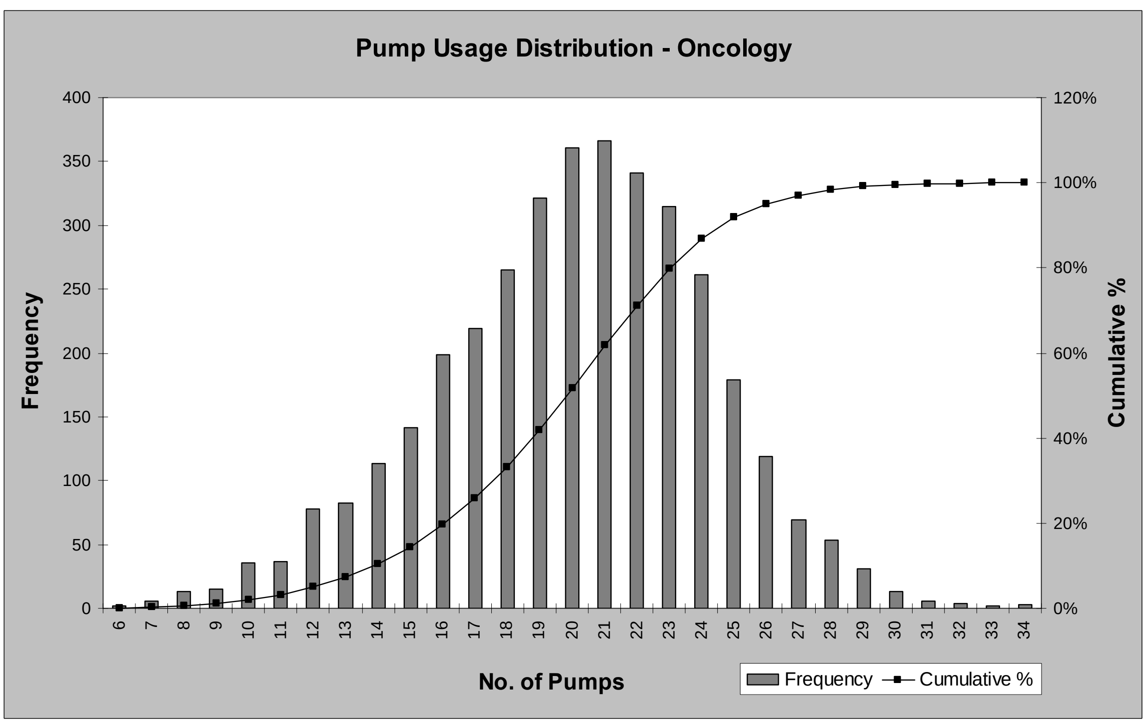


Figure 6-11: Pump Usage Distribution - Oncology

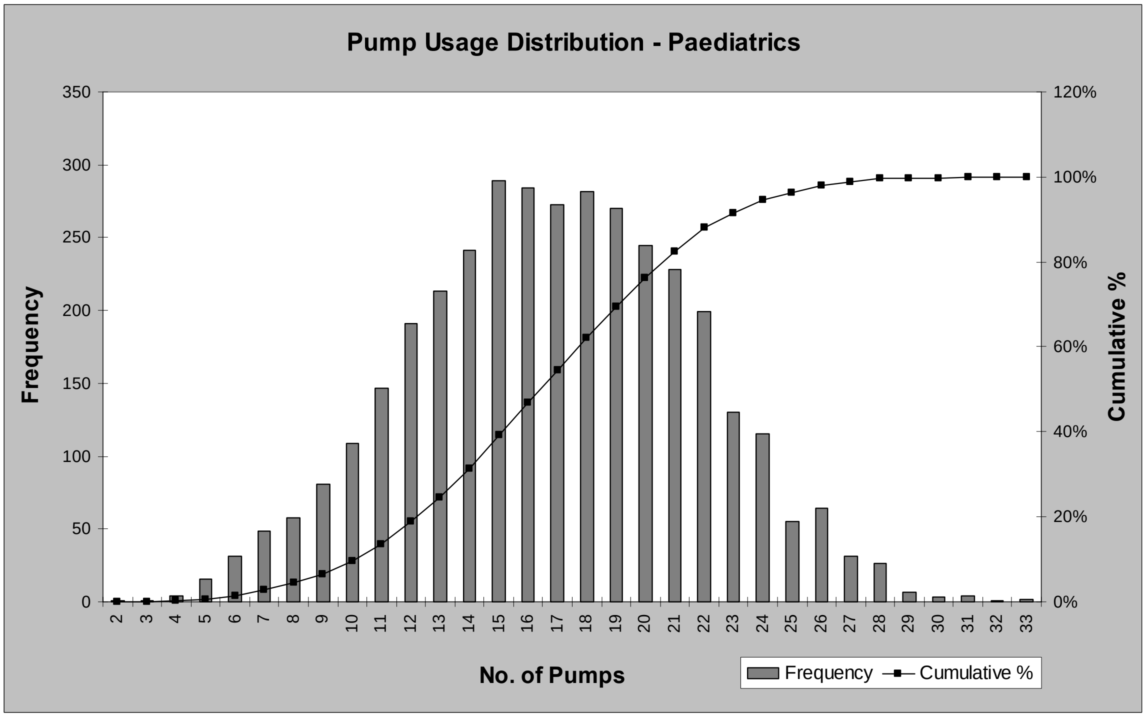


Figure 6-12: Pump Usage Distribution – Paediatrics

The pump usage distributions can be used to determine the number of pumps each department needs on hand to maintain a specified service level if each of the departments were to manage their own set of pumps. For instance, if Paediatrics wanted a 100% service level for pumps, the department should keep an inventory level of 33 pumps. A service level of 98% requires 27 pumps (see Figure 6-12). Table 6-3 illustrates the number of pumps required by each department to meet four various service levels, 95%, 98%, 99%, and 100%. The last row of this table shows the total number of pumps required in the system corresponding to each of the four service levels, if every department maintains a separate inventory level of Pumps.

Table 6-3: Number of Pumps to Maintain in Each Department to Provide Specified Service Levels

Department	Service Level			
	95%	98%	99%	100%
CCU	23	24	25	29
General Surgery	53	57	58	70
ICU	56	60	63	80
Medical Program	21	23	24	29
Oncology	26	28	29	34
Paediatrics	25	27	28	33
Total	**204**	**219**	**227**	**275**

This is, to some extent, a reflection of the current situation, where 224 pumps are available in total. The personnel in each department tend to keep pumps in excess of the department's current use, in anticipation of future need. They avoid giving away their extra pumps to other departments in need. This behaviour is the root cause of the shortage of pumps happening through out the hospital. In practice, the number of pumps in a department could exceed the maximum number of pumps required for that department to meet a 100% service level. When a department stores available pumps without sharing them, another department may be in an intense need for a free pump. This is the cost of not pooling the inventory of pumps. In fact, the total number of pumps actually available should be able to meet 100% service level for the hospital if pumps not in use were immediately available to patients. This issue will be studied further in the upcoming sections, and alternative pump management schemes will be evaluated.

Appendix E includes tables that show the numbers of pumps required for service levels between 0% and 100% (cumulative percentage) for each department.

6.1.2 Shortage or Excess of Pumps

As discussed earlier, the simulation time unit was considered a single "day." At the start of each simulated day, the number of patients admitted to, and released from each department at the end of the previous day was calculated first. Each of the arriving patients to a department (e.g. ICU), require a certain number of pumps (determined by the patient pump requirement probability distribution of that department; see Section 4.3.1). Furthermore, each patient released from that department will free pumps for use by the new patients. If the number of freed up pumps (F_{kir}) was equal to the number of pumps required by the new admitted patients (D_{kir}), the department had zero shortage or excess of pumps on that day. If the number of freed up pumps was more than the number of pumps required by the new patients, the department had an excess of pumps (E_{kir}) on that day. And, if the number of freed up pumps was fewer than the number of pumps required by the new patients, the department experienced shortage (S_{kir})on that specific day, and its staff had to attain required pumps from other locations in the hospital. As a result, two measures of performance, the daily number of pump shortage, and the daily number of pump excess, are easily determined (see equations 6.1 and 6.2).

The Emergency Department is one of the primary entry points of patients to the hospital. This department accepts patients from outside the hospital and sends them to other departments based on patients' needs. In the simulation, this is accomplished via each department's input probability distributions (see Section 4.3.1). Nearly 80% of the patients transferred from the Emergency Department to the other departments take one pump with them. The Emergency Department is in constant need for pumps. This is consistent with what is actually happening in the hospital.

In the simulation, when patients admitted into departments came from the Emergency Department with a pump, the number of pumps these patients required in that department was decreased by one unit. For instance, if a patient from the Emergency Department was admitted into ICU with one pump, and this patient needed three pumps in total, the number of pumps needed when the patient got to ICU was reduced to two. In other words, the daily need for pumps in a department is fewer than the daily number of pumps in use in that department (P_{kir}) since some of the pumps in use are provided by the Emergency Department. The following equations demonstrate the logic explained in this section:

$$E_{kir} = \text{Max}\ [0, F_{kir} - D_{kir}] \tag{6.1}$$

$$S_{kir} = \text{Max}\ [0, D_{kir} - F_{kir}] \tag{6.2}$$

Where,

D_{kir} = Number of pumps required by the new admitted patients in department k, at period i, and replication r

E_{kir} = Number of pumps in excess in department k, at period i, and replication r

S_{kir} = Number of pumps short in department k, at period i, and replication r

$k = 1,\ldots, 7$ (see Table 6-1), $i = 1,\ldots, 365$, and $r = 1,\ldots, 10$

As discussed earlier, when a department faces a pump shortage, its staff go through a time consuming and frustrating process of searching other departments to retrieve a free pump. This process wastes valuable staff time, produces extra cost for the hospital, and reduces the quality of service to patients. Staff reaction has been to prefer to hoard the pumps whenever there is any excess of pumps in their department. This has had an unintended consequence of creating more shortages than there need be due to the prevalence of 'hoarding' pumps not in use. The simulation was built to study the extent of the problem and to quantify the pump shortages. From the outcome of the simulation, the number of pumps in excess and the number of pumps short in each department were calculated on a daily basis. Table 6-4 shows the average number of pump shortage per day, by department ($S_{k..}$).

Table 6-4: Average Number of Pumps Short per Day by Department

Department	Average No. of Pumps Short per Day	Standard Deviation
CCU	1.81	2.83
General Surgery	3.18	4.73
ICU	3.68	5.60
Medical Program	1.58	2.40
Oncology	1.16	1.87
Paediatrics	1.70	2.60
Emergency	12.57	3.66

Table 6-4 shows that the Emergency Department faces the highest volume of pump shortages every day. The reason is straightforward - in other departments, discharged patients free up pumps that the department can use for new admissions. This does not happen in the Emergency Department, as no inpatients exist from previous days.

The average number of pump shortage for the Emergency Department is 12.57 pumps per day. This implies that on each day, on average 12.57 pumps are attached to patients arriving at the Emergency Department, and then sent to other departments along with the patients. 12.57 pumps are divided among different departments as shown in Table 6-5.

Table 6-5: Average Number of Pumps Provided by the Emergency Department per Day

Department	Average No. of Pumps Provided by Emergency, per Day
CCU	1.10
General Surgery	3.73
ICU	0.57
Medical Program	4.61
Oncology	0.58
Paediatrics	1.98
Total	**12.57**

The number of pumps required in the Emergency Department during a one year period, varies from a minimum of 9.1 pumps to a maximum of 16.5 pumps per day across replications. This indicates the variability in the rate of patient arrivals to the Emergency Department.

From a departmental point of view, a number of pumps that are in use each day are provided by the Emergency Department. Table 6-6 shows the percentages of the total number of pumps in use in each of the departments that are supplied by the Emergency Department. For instance, nearly 32% of the pumps in use in the Medical Program Department are provided by the Emergency. This suggests that on average, Medical Program is responsible to retrieve 68% of its total required pumps, whereas, for instance, the Oncology Department should retrieve about 97% of its required pumps.

Table 6-6: Percentage of the Total No. of Pumps in Use Provided by the Emergency Department

Department	% of the Total No. of Pumps in Use Provided by the Emergency
CCU	6.66%
General Surgery	9.56%
ICU	1.62%
Medical Program	31.87%
Oncology	2.90%
Paediatrics	11.75%

In the current situation, pumps that have been freed up by discharged patients in excess of the pump requirements of a department remain in that department until retrieved by another department or until they are used another day in the same department. This indicates that pump shortages in a department is either fulfilled by excess pumps remaining from previous days, or, by the extra pumps retrieved from another department.

It should be noted that the Emergency Department does not ever have any excess pumps since this department is an entry point to the system. This department fulfils its pump requirements solely from the extra pumps available in other departments of the hospital. Table 6-7 shows the average number of pumps in excess per day, by department ($E_{k..}$).

Table 6-7: Average Number of Pumps in Excess per Day by Department

Department	Average No. of Pump Excess per Day	Standard Deviation
CCU	1.83	2.83
General Surgery	3.16	4.67
ICU	3.67	5.63
Medical Program	1.59	2.34
Oncology	1.16	1.76
Paediatrics	1.71	2.51

It should be noted that daily average number of pumps short or in excess is calculated based on 10 replications of 365 days of each department and it is independent from the overall shortage or excess of pumps in the system. For instance, on a specific day, three departments may have 20 pumps in excess and the other four departments have 16 pumps short. On that day, the shortage would be covered by excess of pumps and 4 extra pumps remain for upcoming days. The next day, two departments may have 12 extra pumps and the other five departments have 15 pumps short. These departments fulfill their shortages by excess of the other two departments (12 pumps) and the extra pumps remaining on the floor from previous days. Therefore, the sum of daily average number of pumps in excess (see Table 6-7) is different from the sum of daily average number of pumps short (see Table 6-4). In fact, the total number of pumps in use in the hospital should fulfill the demand for pumps of all departments, and, $S_{k..}$ and $E_{k..}$ are independent from the total number of pumps required in the hospital.

6.1.3 Summary

The simulation provided the mean and the distribution of the number of pumps in use in each of the departments. Using these distributions, the number of pumps required to meet a certain level of service was obtained for each department.

Finally, the number of shortage of pumps per day and the number of excess of pumps per day were quantified for every department. These performance measures are later used to compute the overall labour cost of pump shortages in the current situation, in order to suggest improving alternatives.

6.2 Current System

The problem originally introduced by the clinical directors was that the staff in each department hoarded their extra pumps and refused to give them away to other departments facing pump shortages. This behaviour resulted in long and frustrating search times for staff of the departments that required free pumps for patient care because they did not know where to locate the free pumps. In addition, the total number of pumps actually in each department was not evident.

To evaluate this problem, a model was constructed to simulate the current system of patient and pump flow throughout the hospital. Using the results of the simulation model, the total number of pumps in use, the number of pumps short per day, and the number of pumps in excess per day were calculated for each department. The simulation was run for 10 replications of 365 days each. Tables showing the average of shortage of pumps per day for each department can be found in Appendix F. Moreover, Appendix G contains tables showing the average of excess of pumps per day for each department.

Having quantified the number of shortages of pumps per day, the cost of these shortages can be computed if staff search and retrieval times are available. These times were estimated by soliciting estimates by the clinical directors of each of the departments. The process of retrieving a pump was then broken down into two components: 1- the time to search for a free pump, and 2- the time to fetch the free pump. The time to search for a free pump consists of the time taken to call other departments to ask whether free pumps were available there, then the time the staff took in going to other departments and physically looking for a free pump. This time formed the larger portion (two thirds) of the retrieval time. The average of time to retrieve a pump for all the departments was estimated at 18 minutes, including 12 minutes of search time and 6 minutes to fetch the pump. Based on these times, and the number of pump shortages for each department, the average time spent locating and fetching pumps each day was calculated for all departments. Appendix H contains tables showing daily time (in hours) spent to retrieve pumps for each department during a one year period (the current system). The sum of times spent retrieving pumps in 365 days is presented in Table 6-8.

Table 6-8: Time (Hours) Spent to Retrieve Required Pumps during One Year – Current Situation

Department	Time Spent to Search for Pumps (Hours)	Time Spent to Fetch Pumps (Hours)	Total Time (Hours) Current Situation
CCU	132.34	66.17	198.51
General Surgery	232.26	116.13	348.39
ICU	268.5	134.25	402.75
Medical Program	115.46	57.73	173.19
Oncology	84.7	42.35	127.05
Paediatrics	124.28	62.14	186.42
Emergency	919.92	459.96	1379.88
Total	**1877.46**	**938.73**	**2816.19**

The staff members who usually retrieve free pumps are either from housekeeping, or, clerical personnel. The average hourly wage of these two groups is $20 per hour. The annual labour cost of shortage of pumps can then be calculated using the following equation:

$$TC(cs) = \sum_{k=1}^{7}\sum_{i=1}^{365} S_{ki.} \cdot T_{CS} \cdot C_L \tag{6.3}$$

Where,

$TC\ (cs)$: Annual labour cost of retrieving required pumps, current system

$S_{ki.}$: Average No. of pump shortage in department k at period i,

k = 1,…, 7 (see Table 6-1), and i = 1,…, 365 (days)

T_{CS} : Average time spent to retrieve a pump, current system (hours)

C_L : Average hourly wage of staff who retrieve pumps ($20/hr)

Table 6-9 shows the current annual labour cost of searching for pumps and fetching pumps, separately, and the total annual labour cost of retrieving the required pumps by department.

Table 6-9: Annual Labour Cost of Retrieving Required Pumps by Department - Current Situation

Department	Annual Labour Cost of Searching for Pumps ($)	Annual Labour Cost of Fetching Pumps ($)	Total Annual Labour Cost ($) Current Situation
CCU	$2,646.80	$1,323.40	$3,970.20
General Surgery	$4,645.20	$2,322.60	$6,967.80
ICU	$5,370.00	$2,685.00	$8,055.00
Medical Program	$2,309.20	$1,154.60	$3,463.80
Oncology	$1,694.00	$847.00	$2,541.00
Paediatrics	$2,485.60	$1,242.80	$3,728.40
Emergency	$18,398.40	$9,199.20	$27,597.60
Total	**$37,549.20**	**$18,774.60**	**$56,323.80**

In the current system, no charge is associated with a department holding excess pumps since nothing specific is done for the extra pumps.

As indicated in Table 6-9, on average $56,324 is spent on salaries alone to retrieve required pumps for patient care. Two third of this cost, about $37,549, is the cost of searching for pumps, which is a considerable amount.

In addition to the labour cost, delays in providing a pump for patient care decrease the quality of service. While looking for free pumps, the staff involved in searching and the staff waiting for the pump to arrive become frustrated since they can not predict where and when the free pump would be available. This frustration may also have an impact on the quality of service, and generate an unpleasant work environment. The time staff spend looking for pumps is also time not spent in providing other forms of patient care.

As shown in Table 6-8, about 2,816 hours per year are spent to search for free pumps. This time is 32% of the duration of a complete year. By only looking at search time, if each employee works for 2,080 hours per year, this time represents 1.35 person-years.

In the next section, alternative strategies for pump management are recommended. These strategies are intended to reduce the search time, and to eliminate the frustration caused by not knowing where free pumps are.

6.3 Recommendations: Alternative Pump Management Methods

In order to enhance the current situation, two alternative pump management methodologies were evaluated. Each of these methodologies promised to reduce pump search time by being better able to identify the location of free pumps.

The first approach considered is to pool the inventory of available pumps. Resource pooling is a common approach used to get better utilization of a shared resource such as pumps. The difference between this method and the current process is that every pump is returned to the central pool when not in use. Thus, when a department encounters a pump shortage, the personnel know where to retrieve a free pump. The details of this method will be discussed in the next section.

The second methodology is the use of RFID technology. This strategy was originally considered by the hospital as a technique to overcome the problem of hoarding many kinds of clinical equipment. Over the time this simulation study took place, the hospital assessed the cost of setting up RFID technology for a number of types of clinical equipment, including pumps. The use of RFID technology to identify the pump location was, therefore, one of the alternatives to the current situation that was evaluated in this thesis with respect to the labour cost and time savings it offered. This alternative will be further discussed in upcoming sections.

6.3.1 Central Pooling

This approach involves setting up a specific location in the hospital to keep all the pumps currently available for use. In this method, all 224 pumps (the current inventory of pumps) would be pooled in a central location and all the departments would fulfill their demand for pumps by retrieving free pumps from this central pool. Also, all departments are required to return pumps no longer in use to the central pool. That is to say, they do not retain any free pumps in their department. The most important advantage of using this method is that the location of free pumps is always known, so, the search time and the frustration associated with it will be eliminated.

To evaluate the labour cost savings of this method against the labour cost of the current system, first, the time to retrieve a pump in this method was determined. Since two of the departments, with the highest demand for pumps, Emergency and ICU, are located on the second floor of the main building of the hospital, it was assumed that the central pool was on the second floor (the best location could be optimized by solving the 1-median model). Using the expert opinion previously collected, the average time to fetch a pump from the central pool for all departments was estimated at 6 minutes. Therefore, by using the average number of pump shortages each day, the average time to retrieve free pumps can be calculated for each simulation run.

This method has also another labour cost associated with it, which is the average time to return a free pump to the pool. The average time to return extra freed up pumps to the pool was also assumed to be 6 minutes per pump. Table 6-10 shows the total labour time spent in each department for retrieving and returning pumps during a one year period.

Appendix I includes tables for each department, showing daily time spent (in hours) to retrieve and return pumps during 365 days (the central pooling system).

Table 6-10: Time (Hours) Spent to Retrieve Required Pumps and Return Extra Pumps during One Year – Central Pooling

Department	Time Spent to Retrieve Pumps (Hours)	Time Spent to Return Pumps (Hours)	Total Time (Hours) Central Pooling
CCU	66.17	66.65	132.82
General Surgery	116.13	115.43	231.56
ICU	134.25	133.85	268.10
Medical Program	57.73	58.16	115.89
Oncology	42.35	42.17	84.52
Paediatrics	62.14	62.26	124.40
Emergency	459.96	0.00	459.96
Total	**938.73**	**478.52**	**1417.25**

The annual labour cost of shortage of pumps was calculated using the following equation:

$$TC(cp) = \sum_{i=1}^{365} \{ \sum_{k=1}^{6} [S_{ki.} \cdot T_{FCP} \cdot C_L + E_{ki.} \cdot T_{RCP} \cdot C_L] + S_{7i.} \cdot T_{FCP} \cdot C_L \} \tag{6.4}$$

Where,

TC(cp) : Annual labour cost of retrieving required pumps, central pooling system

$S_{ki.}$: Average No. of pump shortage in department *k* at period *i*

$E_{ki.}$: Average No. of pump excess in department *k* at period *i*,

k = 1,…, 7 (see Table 6-1), and *i* = 1,…, 365 (days)

T_{FCP}: Average time spent to retrieve a pump, central pooling (hours)

T_{RCP} : Average time spent to return a pump, central pooling (hours)

C_L : Average hourly wage of staff who retrieve pumps ($20/hr)

Table 6-11 shows the annual labour cost of retrieving and returning pumps, and the total labour cost when using the central pooling method.

Table 6-11: Annual Labour Cost of Retrieving Required Pumps and Returning Extra Pumps by Department - Central Pooling

Department	Annual Labour Cost to Retrieve Pumps($)	Annual Labour Cost to Return Pumps ($)	Total Labour Cost Central Pooling
CCU	$1,323.40	$1,333.00	$2,656.40
General Surgery	$2,322.60	$2,308.60	$4,631.20
ICU	$2,685.00	$2,677.00	$5,362.00
Medical Program	$1,154.60	$1,163.20	$2,317.80
Oncology	$847.00	$843.40	$1,690.40
Paediatrics	$1,242.80	$1,245.20	$2,488.00
Emergency	$9,199.20	$0.00	$9,199.20
Total	**$18,774.60**	**$9,570.40**	**$28,345.00**

This method provides a significant time savings as compared to the time spent in the current system, nearly 1,400 hours per year, and consequently, a considerable cost savings of $28,000 per year. The Emergency Department benefits the most from this method since it saves almost 920 hours per year due to not having to return any pumps to the pool. In addition to this apparent time saving, 6 minutes to retrieve a pump is an average time for all the departments locating on different floors of the building; with the pool on the second floor, time to retrieve a pump would be a lot less, about 3 minutes, for the Emergency Department and ICU that are located on the second floor. Since these two departments have the highest demand for pumps, substantial time savings and service improvement would be reached with this methodology.

Another advantage of this method is that the demand for pumps throughout the hospital can be satisfied with fewer number of pumps in total. Therefore, the hospital can potentially reduce its capital costs of pump acquisition (the pumps cost approximately $5000 apiece) and the overall pump utilization will increase.

The Simulation model was run for 10 replications of 365 days. For each replication, the number of pumps required overall in the hospital to guarantee a certain service level was determined in central pooling system. Table 6-12 shows the number of pumps that should be maintained throughout the hospital to ensure 95%, 98%, 99%, and 100% service levels for each of the replications. The last row of this table represents the average value of the 10 data points.

Table 6-13 provides summary statistics for the averages, including a confidence interval for the number of pumps required to meet each service level target.

Table 6-12: Number of Pumps to Maintain in the Hospital to Ensure Different Service Levels

Replication	Service Level			
	95%	98%	99%	100%
1	177	184	187	198
2	172	180	182	192
3	173	183	185	203
4	165	171	176	200
5	176	184	187	190
6	171	181	187	193
7	170	176	177	179
8	174	179	184	194
9	170	176	179	185
10	174	181	189	192
Average	**172.2**	**179.5**	**183.3**	**192.6**

Table 6-13: Descriptive Statistics of the No. of Pumps required, by Service Level

Service Level	Mean	Median	Mode	Standard Deviation	Sample Variance	Confidence Interval (95%) Half-Width
95%	172.20	172.50	170	3.46	11.96	2.47
98%	179.50	180.50	184	4.14	17.17	2.96
99%	183.30	184.50	187	4.60	21.12	3.29
100%	192.60	192.50	192	7.03	49.38	5.03

The variation in the data points across the 10 replications is seen to be quite small compared to the mean and the median and thus the confidence intervals are fairly tight. Comparing the sample variance of each of the service levels, the sample variance of the 100% service level is notably larger than the other three sample variance values. This denotes that the peak demand is more variable than the 95%, 98% and even 99% service level. Therefore, the number of pumps to maintain for a service level less than 100% can be predicted with higher confidence. In other words, the lower the service level, the smaller the confidence interval will be.

The confidence interval half-width values of all six departments, of both 95% and 99% confidence intervals, are very small compared to the corresponding mean values. In fact, the variation in sample mean values around population mean is less than 1 pump in 95% of the times, and is less than 1.06 pumps 99% of the time, for all six departments.

Appendix J includes ten tables for ten replications, each consisting of the number of pumps required in the system for all levels of service between 0% and 100% (cumulative percentage)

To estimate the number of pumps required in the system, one method was averaging the results of 10 replications for different service levels (see last column of Table 6-12), and the other method was to analyze all the data points produced by the 10 runs, altogether. Table 6-14 shows the number of pumps required for all service levels (SL), between 0% and 100%, yielded by the later method.

Table 6-14: Number of Pumps Required to Provide Service Levels Between 0% and 100%

# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)
50	.03%	89	.22%	128	22.90%	167	91.73%
51	.03%	90	.25%	129	24.82%	168	92.47%
52	.03%	91	.27%	130	26.74%	169	93.18%
53	.03%	92	.27%	131	28.36%	170	93.86%
54	.03%	93	.30%	132	30.44%	171	94.36%
55	.03%	94	.30%	133	32.11%	172	95.04%
56	.03%	95	.33%	134	33.92%	173	95.64%
57	.05%	96	.38%	135	36.52%	174	96.14%
58	.05%	97	.52%	136	38.25%	175	96.58%
59	.05%	98	.60%	137	40.55%	176	97.12%
60	.05%	99	.77%	138	42.66%	177	97.45%
61	.05%	100	.82%	139	44.52%	178	97.67%
62	.05%	101	1.04%	140	46.60%	179	97.89%
63	.05%	102	1.18%	141	48.93%	180	98.11%
64	.08%	103	1.34%	142	50.52%	181	98.52%
65	.08%	104	1.59%	143	52.71%	182	98.74%
66	.08%	105	1.75%	144	54.88%	183	98.93%
67	.08%	106	2.19%	145	56.90%	184	99.12%
68	.08%	107	2.74%	146	58.77%	185	99.29%
69	.08%	108	2.99%	147	61.21%	186	99.34%
70	.08%	109	3.56%	148	63.18%	187	99.53%
71	.08%	110	4.16%	149	64.96%	188	99.59%
72	.08%	111	4.93%	150	67.10%	189	99.67%
73	.08%	112	5.40%	151	68.96%	190	99.75%
74	.08%	113	6.00%	152	70.33%	191	99.75%
75	.08%	114	6.68%	153	72.27%	192	99.84%
76	.08%	115	7.29%	154	74.05%	193	99.86%
77	.08%	116	8.25%	155	76.05%	194	99.89%
78	.08%	117	9.45%	156	77.64%	195	99.89%
79	.08%	118	10.33%	157	79.15%	196	99.92%
80	.08%	119	11.26%	158	80.55%	197	99.92%
81	.08%	120	12.44%	159	82.47%	198	99.95%
82	.14%	121	13.34%	160	83.78%	199	99.95%
83	.14%	122	14.79%	161	85.23%	200	99.97%
84	.14%	123	16.22%	162	86.44%	201	99.97%
85	.16%	124	17.62%	163	87.92%	202	99.97%
86	.19%	125	19.23%	164	89.04%	203	100.00%
87	.19%	126	20.25%	165	89.89%		
88	.19%	127	21.51%	166	90.96%		

As the last two columns of Table 6-14 show, the rounded number of pumps required to maintain 95%, 98%, 99% and 100% service levels is 172, 180, 184, and 203, respectively (highlighted rows). Comparing these numbers with the averages in the last row of Table

6-12 rounded up, shows that the number of pumps required for 95%, 98%, and 99% service levels yielded by both methods, are mostly the same. Whereas, the values of the number of pumps to meet the 100% service level yielded by each method, are very different from each other (193 against 203 pumps). It was concluded that the later method yielded more accurate estimates of the number of pumps required.

Figure 6-13 presents the pump usage distribution if the hospital uses centralized pump management. This figure also illustrates the number of pumps required for different service levels between 0% and 100% (cumulative percentage).

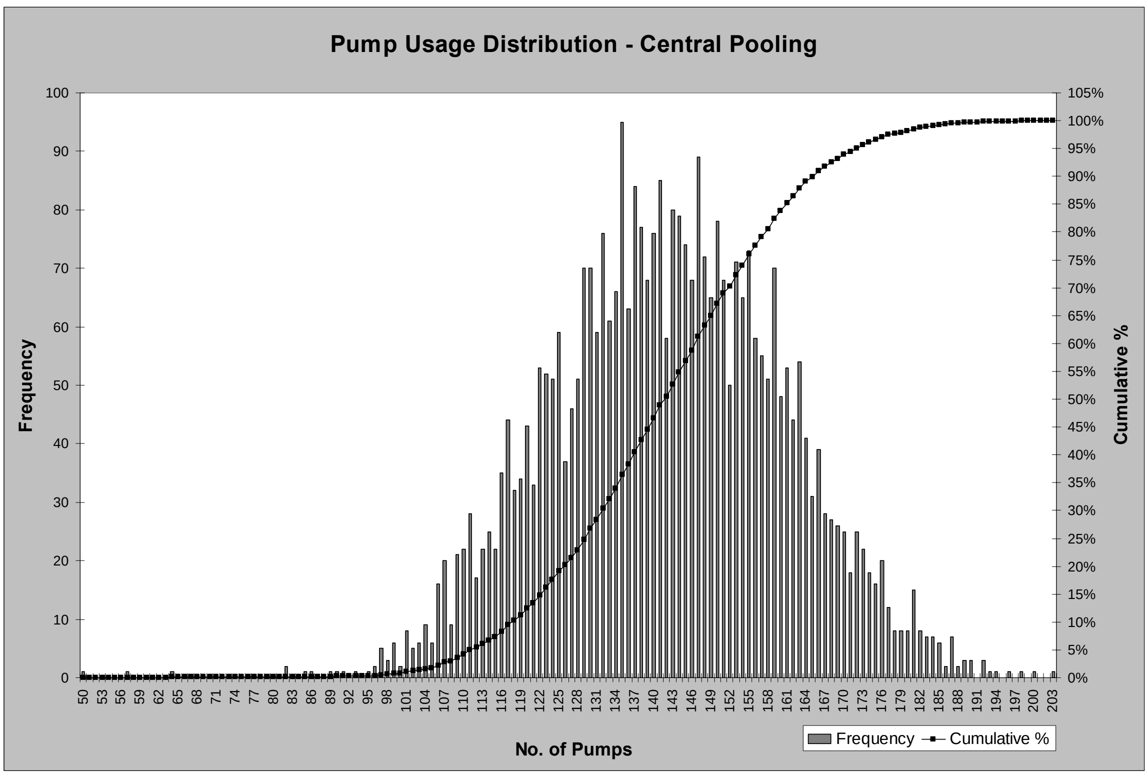


Figure 6-13: Pump Usage Distribution for All Six Departments - Central Pooling

In conclusion, the total number of pumps required in the system, using centralized pump management, is fewer than the number of pumps existing in the current system (224 pumps). As presented in Table 6-3, the number of pumps required to meet, for instance, 99% service levels if each department maintains their own inventory of pumps, is 227 pumps. The number of pumps required to meet a 99% service level in the central pooling system is 184 pumps (see Table 6-14). This, in fact, could prove a significant capital savings to the hospital if they can achieve a 99% service level with approximately 43 fewer pumps.

With the hospital planning to replace the current pumps with newer models, each at $5,000, approximately $200,000 can be saved in capital costs. This is because an inventory of 184 pumps can provide a 99% service level as compared to the current supply of 224 pumps.

Having fewer pumps also increases the pump utilization rate. With the current number of pumps, the simulation yielded a 59% pump utilization rate. Maintaining 203 pumps in the pool, the simulation yielded a 65% pump utilization rate, which is a 6% improvement in rate of pump utilization.

In general, centralized pump management has many advantages over the current situation. However, this method has costs associated with it that should be evaluated before implementing this system. Comparison of centralized pump management system with the current system will be discussed in more detail in Section 6.4.

6.3.2 RFID System

With a proposed RFID pump management system, all the available pumps in the hospital are equipped with RFID active tags. Tag readers are installed in the hospital so that they can receive the radio frequency signals sent by the active tags. Software, which is installed on a mainframe computer, sends commands to the readers, and receives and interprets the data communicated by the readers. The data interpreted by the software indicate the location of each of the active tags that are mounted on the pumps. With an RFID system in place, staff can identify the location of all the pumps when one is needed. They can then retrieve the closest pump. One limitation to the use of RFID tags is the need to find a mechanism to distinguish between pumps in use, and pumps available for use. For instance, if the system shows that a pump is by a bed, it likely implies that the pump is in use. If the pump is in a hallway, the pump must be free.

With RFID system, every department can fulfill its demand for pumps by using the extra pumps existing in other departments. The freed up pumps remain in a department until retrieved by another department. The difference of this method with the current system is that the staff cannot hoard free pumps since the location of each pump is recognizable. This eliminates the search time for free pumps and the frustration associated with it. As with the centralized pump management alternative, the total number of pumps required in the hospital can be reduced due to pooling of resources. In addition to these advantages, using RFID tags yields labour cost savings of searching for available pumps compared to the current system.

To evaluate the labour cost savings of this method the time required to locate and retrieve a free pump was determined using experts' opinion. Clinical directors estimated this time at 10 minutes. Therefore, using the average number of pump shortages per day, the average time to retrieve free pumps was calculated for each simulation replication. Appendix K includes tables for each department, showing the daily time (in hours) spent locating and retrieving pumps during 365 days (the RFID system).

Table 6-15 shows the total labour time (hours) locating and retrieving pumps, by department, during a one year period, using the RFID technology considering a 100% accuracy rate. With this alternative, no labour cost is associated with extra pumps in a department since those pumps remain there until needed by either the same department, or another department.

Table 6-15: Average Time (Hours) Spent to Retrieve Required Pumps during One Year – RFID System

Department	Time Spent to Retrieve Pumps RFID System (Hours)
CCU	110.28
General Surgery	193.55
ICU	223.75
Medical Program	96.22
Oncology	70.58
Paediatrics	103.57
Emergency	766.60
Total	**1564.55**

The annual labour cost associated with pump shortages was calculated using the following equation:

$$TC(rf) = \sum_{k=1}^{7}\sum_{i=1}^{365} S_{ki.} \cdot T_{RF} \cdot C_L \tag{6.5}$$

Where,

$TC(rf)$: Annual labour cost of retrieving required pumps, RFID System

$S_{ki.}$: Average No. of pump shortage in department k at period i,

$k = 1,\ldots, 7$ (see Table 6-1), and $i = 1,\ldots, 365$ (days)

T_{RF} : Average time spent to retrieve a pump, RFID system (hours)

C_L : Average hourly wage of staff who retrieve pumps ($20/hr)

Table 6-16 shows the annual labour cost of retrieving pumps, using the RFID technology.

Table 6-16: Annual Labour Cost of Retrieving Required Pumps by Department – RFID System

Department	Annual Labour Cost to Retrieve Pumps – RFID System ($)
CCU	$2,205.67
General Surgery	$3,871.00
ICU	$4,475.00
Medical Program	$1,924.33
Oncology	$1,411.67
Paediatrics	$2,071.33
Emergency	$15,332.00
Total	**$31,291.00**

This method provides a considerable time saving versus the time spent in the current system (about 1,250 hours per year), and consequently, a significant saving in cost (about $25,000 per year).

As mentioned before, the accuracy rate of RFID system was assumed to be 100%. However, if in practice the accuracy rate of the system is lower than 100%, or a pump that is assumed to be free is in fact in use, additional effort should be put into process of searching for a free pump. In this case, the capability of the system, and accordingly the cost savings reduce. Table 6-17 presents a sensitivity analysis of the annual labour cost of retrieving pumps using the RFID technology with different levels of accuracy rate. The search time is doubled for the cases in which the first attempt to retrieve a free pump is unsuccessful.

Table 6-17: Comparison of Annual Labour Cost of Pump Retrieval Using the RFID System with Different Accuracy Rates

Current System	RFID (100%)	RFID (95%)	RFID (90%)	RFID (80%)	RFID (70%)
$56,323.80	$31,291.00	$32,855.55	$34,420.10	$37,549.20	$40,678.30

The cost savings of the RFID system must be compared to the cost of implementing this technology. According to primary estimates of one of the vendors for the RFID pilot project, an initial cost of about $195,000 would cover the completion of the wireless infrastructure, installation of the hardware and software of the system, and 250 active tags. The cost of training the staff should also be added to this initial cost. In addition to the primary capital cost, the cost of annual maintenance exists for the RFID system. According to the hospital staff, annual maintenance costs are estimated at about $14,000. Considering this annual cost against the annual labour cost savings of this system with 100% accuracy rate, which is $25,000, the annual cost savings of using the RFID technology, excluding the initial investment, will be around $11,000.

A number of the advantages of RFID system are similar to central pooling system. With RFID tags always sending the signal to the readers, the location of pumps is always known, so, the search time and the frustration associated with it will be reduced. In addition, in this system fewer number of pumps is required than the number of existing pumps in the currents system (see Table 6-14). With the hospital planning to replace the current pumps with newer models, each at $5,000, approximately $200,000 can be saved in capital costs. This is because an inventory of 184 pumps (the same as in centralized pooling system) can provide a 99% service level as compared to the current supply of 224 pumps. Having fewer pumps compared to the current system also increases the pump utilization rate. Maintaining 203 pumps in the system yields a 6% improvement in rate of pump utilization.

Comparison of RFID pump management system with the current system will be discussed in more detail in the next section.

6.4 Comparison of the Current System with the Two Alternatives

In this section, a comparison is made between the current system and the two alternatives: centralized pump management and use of an RFID system. Advantages and disadvantages of each of these methods are also discussed.

The most important issue that the hospital is facing with the current system is that when a need for a pump arises in one of the departments, the staff do not have a fast and convenient means of finding a free pump. The search is usually frustrating for both the staff searching for the pumps and the staff waiting for pumps since they can not be certain where a pump will be located and how long this will take. This process not only affects the quality of patient care, but also creates an unpleasant work environment. In addition, every minute of delay to find a pump generates unnecessary costs for the hospital. Due to this frustrating search process, the staff tend to hoard any extra pumps in their department in anticipation of future needs. However, this reaction simply adds to the problem. In both alternatives, the central pooling and the RFID system, the problem of not knowing the location of pumps is reduced. Therefore, the delay and frustration existing in the current system is decreased, and the quality of service is increased.

In the central pooling system, it is known that free pumps can be found in a specific location (central pool). Thus, the average time to retrieve a pump from the pool is known for each department. However, for the pool not to be empty, each department has to return their extra pumps to the pool when they become available. According to Gentles (2000), a survey of a number of hospitals in Toronto area which used central pooling for their pump management, showed that the level of pump availability in the pool was still low, due to the staff continuing to hoard the extra pumps. The author mentioned that an inventory control method should be carried out to keep track of the pumps. Gentles used barcode technology for the inventory control method and charged the nursing units using new infusion pumps with a rental fee (Gentles, 2000). This, in fact, prevents hospital staff to continue hoarding freed up pumps. Fahlstrøm et al. (2006) performed equipment pooling in a hospital in Oslo. After a six month trial period, they concluded that not all departments return their extra equipment to the pool and suggested that a staff member walk around the hospital, collect the extra equipment, and deliver them to the pool. Both of these recommendations (inventory control method and allocating a person to collect equipment) generate extra cost for the hospital, and should be studied in practice in order to identify the best strategy for the Grand River Hospital.

In the RFID system, at any time that a need for pump arises, the location of all the pumps equipped with a RFID tag can be identified by checking a computer system. The staff member checking the system decides which pump should be picked up, and sends someone to retrieve that pump. While the average time to retrieve a free pump will not be reduced to zero, it will be lower than the time taken in the current system. One disadvantage of the RFID system is that tag only provides the pump location, and not whether the pump is in use. Therefore, a protocol needs to be in place to distinguish between free pumps and those in use. For example, pumps that are not located by a bed are assumed to be free. Hoarding the extra pumps can be easily accomplished by locating the free pumps near the beds.

Another advantage that both the central pooling system, and the RFID system have over the current system, is the savings in average annual labour hour and labour cost of retrieving pumps. Table 6-18 shows the annual labour hour and annual labour cost of each of the departments in each of the systems. The average annual labour hour savings of the central pooling system and the RFID system against the current system is 1399 hours and 1252 hours, respectively. The average annual labour cost savings of the central pooling system and the RFID system against the current system is $27,987 and $25,032, respectively. Both of these figures present considerable annual savings.

Both central pooling system and the RFID system generate one more cost saving for the hospital. As explained in detail earlier, the number of pumps required in the hospital, using one of the alternative methods, is lower than the number of existing pumps. When the hospital replaces the existing pumps with more advanced models, they would need to consider purchasing 184 pumps, rather than 224 pumps (for a 99% service level). Considering an estimate of $5,000 per pump, a $200,000 capital savings will result. This amount is a significant saving in capital that should be taken into account when evaluating the initial cost of central pooling or RFID system as an alternative to the current system. In addition to the capital cost savings, the advantage of using fewer number of pumps is that it results in at least 6% increase in the rate of pump utilization (59% against 65%), and also produces a decrease in the annual pump maintenance cost of the pumps. This should be noted that both of the alternative methods have associated capital and operational costs that should be compared with the cost savings of each method before making the final decision. For instance, according to primary estimates of one of the vendors for the RFID pilot project, the initial cost of installing the system is about \$195,000 and the cost of annual maintenance is about \$14,000. For the central pooling system, the cost of space required for the pool and the cost of maintaining the pool (e.g. recruiting a person to manage the pool) should be calculated.

The comparison of the three proposed methods of pump management maintaining the same service level is summarize in Table 6-19.

Table 6-18: Comparison of Annual Labour Hour and Annual Labour Cost of Pump Retrieval in Each of the Three Systems by Department and in Total

Department	Average No. of Shortage of Pumps	Average No. of Excess of Pumps	Labour Hour Current System	Labour Cost Current System ($)	Labour Hour RFID System	Labour Cost RFID System ($)	Labour Hour Central Pooling	Labour Cost Central Pooling ($)
CCU	661.7	666.5	198.51	$3,970.20	110.28	$2,205.67	132.82	$2,656.40
General Surgery	1161.3	1154.3	348.39	$6,967.80	193.55	$3,871.00	231.56	$4,631.20
ICU	1342.5	1338.5	402.75	$8,055.00	223.75	$4,475.00	268.10	$5,362.00
Medical Program	577.3	581.6	173.19	$3,463.80	96.22	$1,924.33	115.89	$2,317.80
Oncology	423.5	421.7	127.05	$2,541.00	70.58	$1,411.67	84.52	$1,690.40
Paediatrics	621.4	622.6	186.42	$3,728.40	103.57	$2,071.33	124.40	$2,488.00
Emergency	4599.6	0	1379.88	$27,597.60	766.60	$15,332.00	459.96	$9,199.20
TOTAL	**9387.3**	**4785.2**	**2816.19**	**$56,323.80**	**1564.55**	**$31,291.00**	**1417.25**	**$28,345.00**

Table 6-19: Comparison of the Current System with the Two Pump Management Alternatives

		Characteristics for Comparing the Two Alternative Methods with the Current System	Centralized Pooling	RFID Technology
Advantages	Qualitative	Quality of Patient Care	Increases	Increases
		Pump Location Awareness	Increases	Increases
		Frustration	Decreases	Decreases
		Work Environment Satisfaction	Increases	Increases
	Quantitative	Search Time	Decreases	Decreases
		Labour Cost	Decreases	Decreases
		Number of Required Pumps	Decreases	Decreases
		Pump Purchase Capital Cost	Decreases	Decreases
		Pump Maintenance Cost	Decreases	Decreases
		Pump Utilization Rate	Increases	Increases
Disadvantages	Qualitative	Hoarding the Unused Pumps	Still Exists	Still Exists
		Behavioural Implementation Issues	Are Included	Are Included
	Quantitative	Initial Set up Cost	Is Included	Is Included
		Annual Operation Cost	Is Included	Is Included
		Staff Training Cost	Is Included	Is Included

In conclusion, both of the alternative systems, central pooling and RFID, have valuable advantages. Applying one of these methods is highly recommended to the hospital since it not only solves the existing problem of unknown location of free pumps, but also benefits the hospital in various ways that were discussed in detail in this chapter.

Estimating the initial and ongoing cost of maintaining the central pooling system and the RFID system is out of the scope of this project, however, these costs should be investigated in detail before making any definite decision to implement one of these methods.

6.5 Summary

This chapter presented the results from the experimental runs. The daily number of pumps in use in each of the departments were quantified and plotted on the diagrams (see Figure 6-1 through Figure 6-6). The probability distribution of pump usage was also presented for each department. Using these distributions, the number of pumps required to meet a certain service level was obtained for each departments. Pump usage distribution for all departments together was determined and schemed on diagram to evaluate the actual number of pumps required in the system (see Figure 6-13). The number of pumps short per day and the number of pumps in excess per day, by department was also calculated.

The analysis continued by studying the current pump management system, and calculating the number of hours and the cost of labour to retrieve free pumps when required, during a one year period. The original problem of pump management that caused long searches along with frustration for the staff was examined, and two alternative methods were recommended to eliminate this issue.

The first alternative was to utilize a centralized pool to keep all shared pumps when they are not in use. The second alternative was to install RFID technology throughout the hospital and equip all pumps with RFID tags so that they could be easily located. The number of hours and the labour costs of retrieving pumps were also calculated for both of these methods. Finally, the three pump management systems (current, central pooling, and RFID) were compared, and the advantages and disadvantages of each of the alternative techniques were discussed.

Chapter 7: Conclusions and Discussion

7.1 Conclusions

The objective of this thesis was to better understand the patterns of pump use throughout the GRH in order to provide guidance to the hospital on alternative pump management methods. The current system was thoroughly studied to identify the problem. The departments of the hospital encountered shortage of pumps during the day and the staff suffered from searching for pumps throughout the hospital without knowing where to locate a free pump. The hospital suggested that the staff hoarded extra pumps in prediction of future need for pumps in their department. This created frustration for everyone looking for a free pump and reduced the quality of service.

In summary, 317 pumps were available in the hospital for all the departments to share. A number of departments held an inventory of pumps due to their particular operation and location. These departments were excluded from the study, leaving 224 pumps. The data of patient admissions to these departments, length of stay of each patients, number of pumps required for each patient, and patient transfers between the departments were collected and a model reflecting the flow of patients was developed. This model was operationalized by constructing a simulation model. The model presented the flow of patients and pumps through the hospital on a daily basis. The output of the simulation model provided the daily number of pumps in use in each of the departments and the distribution of pump use for each department. Using these distributions, the number of pumps required to meet a certain service level was obtained for each department. From the results of the simulation, the number of pumps short per day and the number of pumps in excess per day were calculated for each department.

The distribution of pump use for all departments together was also determined and it was concluded that the actual number of pumps required in the system is fewer than the number of pumps existing in the hospital. This conclusion confirmed that long searches for free pumps were not due to insufficient quantity of pumps but were because of the behaviour of hoarding extra pumps when available.

In the current system, the personnel were not clear on where available pumps might be stored. Therefore, two alternatives in which the locations of free pumps were known were recommended. The first alternative was to utilize a centralized pool to keep all shared pumps when not in use. The second alternative was to install RFID technology throughout the hospital and equip all pumps with RFID tags so that they could be easily located. The number pumps required in the system, the number of labour hours, and labour costs of retrieving pumps were calculated for both of these methods. It was concluded that in both of the methods fewer number of pumps was required in the hospital. This can result in capital cost savings when replacing current inventory of pumps with the newer models. It also increased the pumps utilization rate and decreased the total annual maintenance cost for pumps. Both methods also produced labour cost savings according to eliminating long search times for free pumps. Most importantly, these methods would reduce the frustration of searching for free pumps and would create a more pleasant work environment. Prompt availability of the pumps would also increase the quality of patient care. The cost savings of both of the alternative pump management strategies is presented in Table 6-18. The initial and ongoing cost of maintaining the two methods should be studied in depth before making the final decision.

Unfortunately, the behavioural issue of hoarding the pumps could be still present in different ways when using the alternative strategies. A solution should be investigated to prevent the problem of not returning the free pumps to the pool, in the central pooling system, or locating the pumps by the beds to falsely represent the pump as ‘in use,’ in the RFID system.

The distinctive contribution of this study was to quantify the actual number of pumps required in the system, which was not previously presented in the literature. A 17% reduction in the number of pumps available in the hospital could still provide a 99% service level. The study also quantified the benefits of inventory pooling.

In summary, this thesis studied thoroughly the flow of patients and pumps in the hospital and recommended alternative pump management methods that could help the hospital to overcome the problem of searching for free pumps when in need.

In general, asset management in health care is a broad area of study with high potentials of improvement. Research similar to this study can considerably benefit the health care industry.

7.2 Suggestions for Future Research

This study was based on an actual pump management system in a hospital setting; therefore, the research was restricted to certain constraints, such as the level of details in the utilized data, or, the availability of the recorded data. As a result, this study can be extended in a number of directions. In addition, although this research was in an applied setting, it facilitated the process of looking into more analytical models and adding to theoretical knowledge of inventory pooling, or to the applied research dealing with generic health management problems.

A conclusion that was drawn from this study was that implementing pooling strategies has more than the technical aspects, which were commonly studied in the literature. The behavioural complications that prevent achieving the full effects of the centralized pooling, and the RFID system should be taken into account. In fact, this is a socio-technical system where the technology is surrounded by people. A socio-technical system includes both technical and human/social aspects that are tightly bound and interconnected (socio technical systems, 2006). "The technical system includes machinery, processes, procedures and a physical arrangement. The social system includes people and their habitual attitudes, values, behavioral styles and relationships (socio technical systems, 2006)." Achieving the full benefits of the centralized pooling system and the use of RFID technology depends on how successful behavioural changes will be. This aspect can be deeply studied in the future.

Another recommendation for future research is to quantify the potential benefits of inventory pooling and the use of RFID technology. In other words, to perform the calculation of exact capital and annual operating cost of the central pooling system and the RFID system. The capital cost of the RFID system includes the complete installation cost of the system and the cost of training the staff. The capital cost of the central pooling system includes the cost of the space allocated to the pool, the cost of introducing an inventory management system, and the cost of training the staff. The annual operational cost of the RFID system consists of the cost of maintenance of the system and the cost of replacing a number of RFID tags on every year. Annual operational cost for the pooling system can be the cost of maintaining the pool and the inventory system. By applying the central pooling or the RFID method, fewer number of pumps is required in the hospital, therefore, the exact price for newer models of the pumps and the annual maintenance cost per pump should be calculated to determine the savings in capital and annual cost yielded by applying these alternative strategies. With these precise cost figures, the actual savings of each of the central pooling and the RFID method will be attained and more informed decisions can be made for replacing the current system. In addition, by quantifying the benefits of the two systems, more analytical models can be developed to capture the trade offs between implementing either of the alternative methodologies, and maintaining the current system.

This study can be extended by modifying the assumptions of the existing model, and based on the new assumptions, presenting the input data differently. The simulation model can be further refined, and, more comprehensive research can be done on the output data to obtain additional results.

One of the assumptions in this study was that the patients, who need to be connected to one or more pumps, have the pumps attached to them during all their stay period in a department. In other words, the length of stay of inpatients was equal to the time the pumps were attached to them. In fact, in reality, most of the patients are connected to one or more pumps at the beginning of their treatment, and as time passes, the patients get better and the number of pumps attached to them reduces. Some of the patients are even disconnected from all their pumps a few days before their release from the hospital. The length of the pump connection to the patients was not recorded in any database, and it was difficult for the experts to estimate it accurately. To obtain this information, an exhaustive on site data collection should have been conducted, which was implausible for this research; however, this research can be extended by gathering these data, and inputting the distributions of the length of stay of the patients and the distributions of the length of pump connection to the patients into the simulation model separate from each other.

In this study, only departments that were heavy users of pumps were considered. Future work can be done by considering all the pump users in the hospital, and including outpatient pump utilization. In addition, some of the departments consist of a number of divisions. Patient flow exists between these divisions and by gathering the information of pump usage for each of these sections, they can be presented individually in the simulation model. For instance, General Surgery Department consists of 3 sections, 6DN, 6DS, and 6C; or Medical Program includes 4 sections, 5DN, 5DS, 5C, and 5A. This level of detail may have not been necessary for the purpose of this research; however, it may be beneficial for exact cost-benefit analysis in order to replace all the pumps existing in the hospital.

A key assumption in this study was that all the available pumps have one channel; however, in the actual system a number of pumps are double-channel, meaning that two different medications can be managed at the same time. In other words, each pump can play the role of two pumps when required for a patient. Separating the two types of the pumps in the simulation model would have made it very complicated and unfeasible, but having double-channel pumps in the actual system may yield fewer number of required pumps in total, and more savings for the hospital.

One last modification in the input data that could be offered for the future research is that the number of data points used for input data was 121. On the other hand, the simulation was run for one year. Using more data points would yield a more precise input distribution. Thus, a suggestion is to use the input probability distributions that are based on actual 365 data points rather than 121 data points.

The output data can also be analyzed more thoroughly. The first suggestion for future research regarding the output data is the calculation of the average time to retrieve a pump from the pool, individually for each department. In this research the average time to retrieve a pump was determined 6 minutes (the average time to access the pool for all the departments). However, different departments are located in different distances from the central pool and their time to access the pool differs within a range of 3 to 10 minutes. Therefore, by calculating the average time to retrieve a pump separately for each department, and considering the demand for pumps is different for every department, the final result of the time savings of central pooling system will be different. The Emergency Department and the ICU are located on the second floor and the pool is also recommended to be on the second floor. These two departments have the highest demand for pumps and, with the pool on the second floor, have the lowest time to access the pool. Therefore, the annual time savings of the central pooling system with individually calculated time to retrieve a pump by department will most likely be more than the annual time savings that were calculated in this study using a constant average time to retrieve a pump from the pool for all departments.

Appendix A

Patient Care Departments

Cardiology

The cardiac services provide care for patients with primary and secondary cardiac disease. These services are conducted in cardiac care unit (CCU). CCU consists of nine beds, which are used for the admission, care, and treatment of patients in the critical stages of a cardiac event, such as a heart attack, heart failure, or life-threatening heart rhythm disorders. CCU is equipped with technological support, including close, continuous observation, and early detection and intervention.

Cardiac patients who can be cared for as outpatients are managed through the use of a day bed. Patients are admitted to this bed for procedures such as pacemaker insertions, intravenous drug therapy, and elective cardioversions. These patients are admitted and discharged on the same day. As part of the continuum of care, cardiology offers an education and support group on an outpatient basis, as well as follow-up phone calls to all heart attack and newly diagnosed angina patients who have been discharged.

Childbirth Services

At the K-W Health Centre of Grand River Hospital, they operate one of the largest community, hospital-based obstetrical services in Ontario, with approximately 4,000 births annually. These services include support through inpatient and walk-in clinics from early pregnancy to one-month post delivery.

Children's Services

At the K-W Health Centre of Grand River Hospital, they provide level II paediatric and neonatal inpatient services along with specialized outpatient clinic services. Specialized outpatient clinics are provided for paediatric oncology, juvenile diabetes, cystic fibrosis, premature follow-up and general outpatient services.

Complex Continuing Care

Complex continuing care is located at the Freeport Health Centre of Grand River Hospital. It provides an accessible and seamless network of medical and restorative services for those individuals living with or recovering from a chronic illness, across the continuum of care and in partnership with other providers. Their patients receive a defined multidisciplinary assessment and treatment with a finite length of stay. It offers the following programs:

Geriatric Assessment: This is a comprehensive interdisciplinary geriatric assessment program that includes an observation period to evaluate the results of treatment and is aimed at developing a personal discharge plan that includes education to support family members and links to the community.

Functional Enhancement: This is a low intensity, functionally focused reactivation program and is aimed at returning patients to home or to a lower level of care.

Medically Complex: This is a resource for patients with chronic and complex clinical conditions requiring a range of multidisciplinary diagnostic and therapeutic services and technologies, and is aimed at discharging patients to their homes or to a lower level of care.

Dialysis

The renal program at Grand River Hospital is one of the largest programs within a community hospital in Ontario. It is the only dialysis program in the region. In the program there is a full-care hemodialysis unit, an assisted care hemodialysis unit, and a satellite hemodialysis unit in Guelph. Most patients need training to learn how to assist in running the dialysis machine. The training takes place at Grand River Hospital in the renal clinic. Their team also train people for home peritoneal dialysis at the renal clinic. In addition, they run a predialysis clinic, which provides medical care, education, and support for people who have some degree of kidney failure, but do not require dialysis.

The renal clinic also organizes assessment of patients who wish to be referred to a kidney transplant program.

Emergency

Grand River Hospital operates the largest emergency department in the Waterloo Region. Their staff members provide paediatric and adult emergency care 24 hours a day, 7 days a week. The department serves 50,000 patients each year with 15,000 of these patients being children. Specialized emergency services are offered including cardiology, renal, mental health, surgery, and paediatrics. Each year the department grows by five percent.

Geriatric Care

Grand River Hospital offers a variety of inpatient and outpatient specialized geriatric services. These programs are located at Grand River Hospital's Freeport Health Centre where they assess, provide diagnostic investigations, treatment and care planning to patients with complex geriatric and medical conditions.

Intensive Care

Grand River Hospital's intensive care unit (ICU) provides care for adults and children with acute, life threatening medical conditions due to illness, injury, or elective intervention, in which one or more vital systems are impaired. ICU consists of twelve acute patient beds. Patients who require more intensive treatment are derived from emergency referral, elective surgical cases and other areas of the hospital. The unit provides intensive nursing, invasive and non-invasive monitoring, respiratory support, dialysis and other therapeutic interventions designed to restore and maintain stability, leading to transfer to a less intense level of care at the earliest time possible.

Medical Imaging

Medical imaging program offers a wide range of therapeutic and diagnostic exams to service outpatients, inpatients, and emergency patients. It provides the following services:

- CT Scan
- Ultrasound
- General X-rays
- Interventional Procedures
- Mammography
- Barium Studies

At medical imaging, they are currently upgrading their facilities to introduce PACs imaging to the department. This system will allow physicians to view their patient's images directly from their own office.

Palliative Care

Patients requiring pain and symptom management and palliative care are admitted to specialized units at either the Kitchener-Waterloo Health Centre or Freeport Health Centre of Grand River Hospital. The palliative care unit, located at Freeport Health Centre, provides comfort and symptom management to patients with cancer and other terminal illnesses. Patients are discharged home if possible, once their symptoms are controlled. The pain and symptom management department is a six-bed unit located at the K-W Health Centre. Patients with a diagnosis of cancer who require acute care interventions are admitted to this unit for investigation and symptom management.

Psychiatry and Mental Health

Psychiatric and mental health program offers a wide range of services to adults, preschoolers, children, adolescents, and their families in Waterloo Region. It's specialized, multidisciplinary teams provide crisis intervention, day treatment, outpatient treatment and consultation, withdrawal management, and short-term hospitalization.

Rehabilitation Program

General Rehabilitation Unit is located at Freeport Health Center of Grand River Hospital. General rehabilitation is an inpatient therapy program that provides rehabilitation care for inpatients who are stable, require and are able to tolerate therapy sessions of between one and three hours daily, over a period of ten or more days. Most common cases are patients with neurological impairment, followed by pulmonary, amputations, and injury related cases. Clients are accepted from 16 years of age, although the average age of current clients is approximately 64 years of age. Referrals are accepted from throughout the Waterloo Region.

K-W Health Center's short stay rehabilitation program offers inpatient rehabilitation to surgical and medical patients whose needs can be met within seven to ten days.

Special Testing

The special testing unit is located in K-W Health Center of Grand River Hospital and is made up of six very unique labs providing a variety of cardio-respiratory and neurology tests. It offers the following tests:

- Pulmonary Function Studies
- Bronchial Challenge
- ABG's (arterial blood gases)
- Exercise Oximetry

- Cardiac Stress Testing
- Holter Monitor
- Echocardiogram
- Electroencephalogram (EEG)
- Electromyography (EMG) and Nerve Conduction Studies
- Surgical Services

Surgical services program supports a diverse range of surgical procedures. The surgical team members including surgeons, nurses, and health care professionals work closely with all departments within the hospital to provide patients with optimum health care services. Clinics and services provided include:

- Pre-Admit Clinic - prepares the adult and paediatric, elective and urgent patients for their procedure, initiating education and discharge planning.
- Day Surgery - provides same day admission for all surgical patients.
- G.I./Endoscopy - provides care to patients having procedures such as colonoscopy, gastroscopy, and flexible sigmoidoscopy, before, during, and post procedure.
- Inpatient Surgery - provides care to all adult surgical patients, pre-and post-operatively.
- Progressive Surgical Unit - provides care for acutely ill surgical patients that require close observation and intense nursing care.
- Operating Rooms - there are 7 available operating rooms that provide peri-operative care for all surgical patients.
- Post-Anaesthetic Care Unit - provides post-anaesthetic care for all surgical patients, providing separate space for children with attending parents. PACU provides post procedure care for diagnostic imaging procedures.

- Outpatient Surgical Clinic - provides outpatient minor surgical procedures that may require local anaesthesia.
- Gynaecology/Laser Clinic - provides outpatient gynaecological procedures as well as the newborn circumcision clinic.

Fracture Room Clinics – provides orthopaedic services such as casting, splinting, post-operative surgical dressing changes and suture removal, injections, aspirations, closed reductions of fractures, and removal of surgical hardware. This clinic also provides urgent care services in working closely with emergency and diagnostic imaging department.

The Grand River Regional Cancer Centre

The Grand River Regional Cancer Centre (GRRCC) is an integrated program of Grand River Hospital in partnership with Cancer Care Ontario. It is the main provider of systemic treatment as well as the sole provider of radiation treatment in the region of Waterloo. GRRCC is a leader in supportive care services to benefit both patients and their families, providing a spectrum of services that include social work, nutrition counselling, spiritual care, physiotherapy, occupational therapy and education. Research support services and data collection are also accessible in coordination with other providers. The following services are offered by the Cancer Centre:

- Systemic Therapy
- Prevention and Early Detection
- Surgical Oncology
- Supportive Care
- Radiation Therapy
- Inpatient Oncology

The Inpatient Oncology unit has existed for many years within the Kitchener-Waterloo Health Centre. The Unit is now a program of the Grand River Regional Cancer Centre (GRRCC). However, Oncology department is located on the 8th Floor of the K-W Health Centre and lacks direct access to the GRRCC next door.

Appendix B

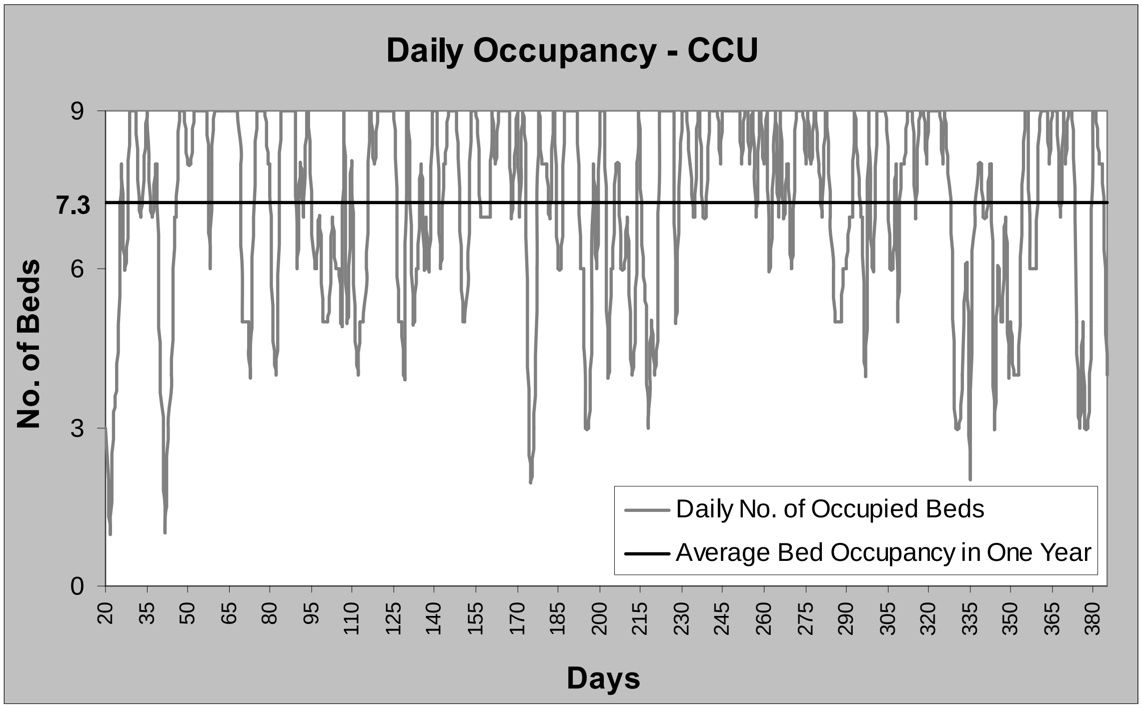
Results of Equal-Width Chi Square Test with the Best Models

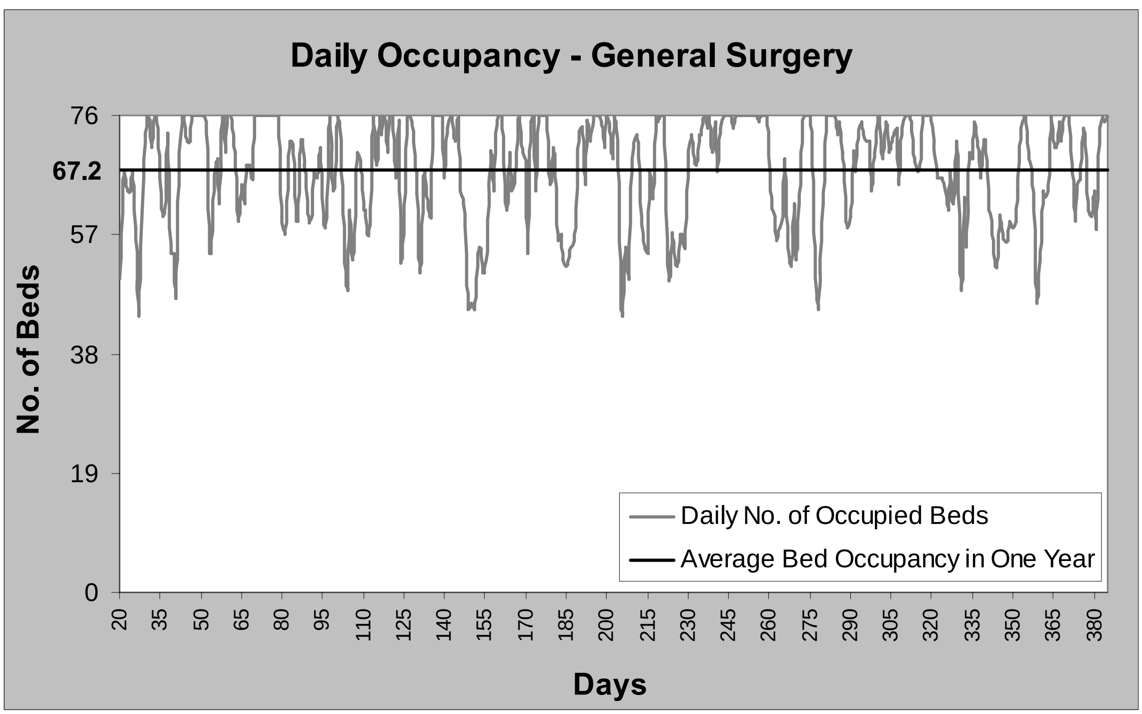
Fitted to the Input Data (15 Entry Points)

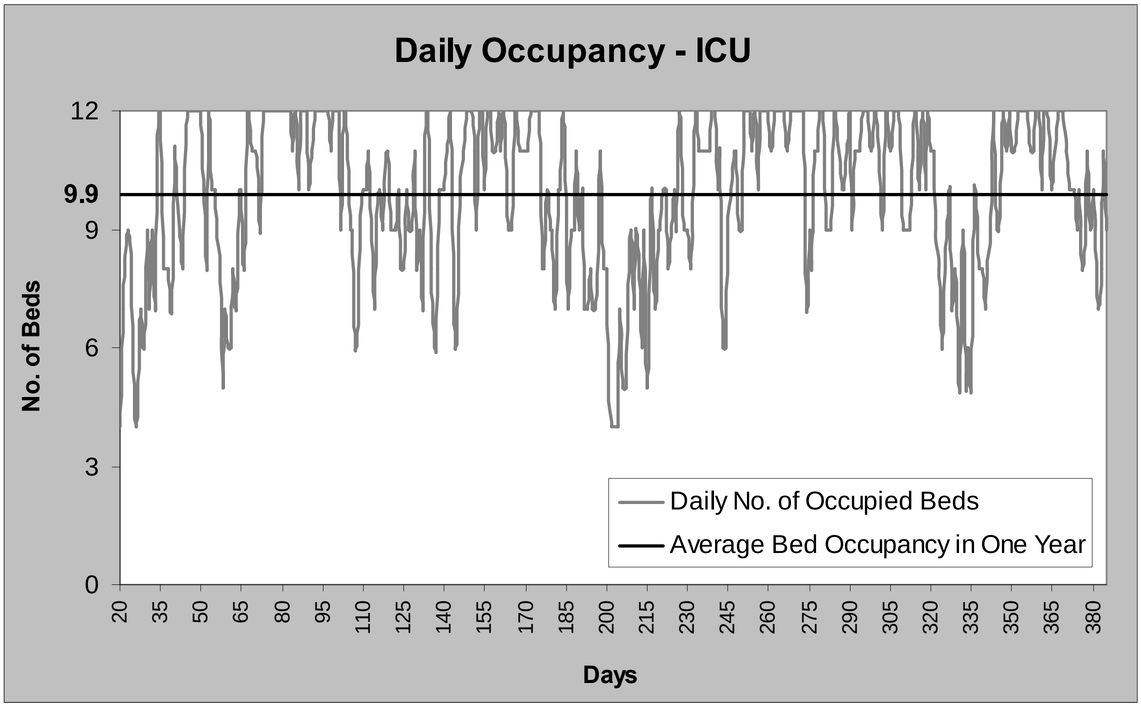
Entry Point	Model	Degree of Freedom	Observed Level of Significance	Critical Value for Level of Significance (α = 0.25)
Direct Admit to CCU	Negative Binomial	3	0.562	4.108
Direct Admit to General Surgery	Negative Binomial	19	0.951	22.718
Direct Admit to ICU	Negative Binomial	3	0.96	4.108
Direct Admit to Medical Program	Negative Binomial	11	0.076	13.701
Direct Admit to Oncology	Negative Binomial	7	0.081	9.037
Direct Admit to Paediatrics	Negative Binomial	5	0.864	6.626
Emergency to CCU	Binomial	4	0.765	5.385
Emergency to General Surgery	Negative Binomial	12	0.878	14.845
Emergency to ICU	Poisson	4	0.351	5.385
Emergency to Medical Program	Negative Binomial	11	0.976	13.701
Emergency to Oncology	Negative Binomial	5	0.445	6.626
Emergency to Paediatrics	Poisson	9	0.47	11.389
Day Surgery to General Surgery	Discrete Uniform	18	0	21.605
Day Surgery to ICU	Poisson	3	0.907	4.108
Day Surgery to Paediatrics	Geometric	2	0.106	2.773

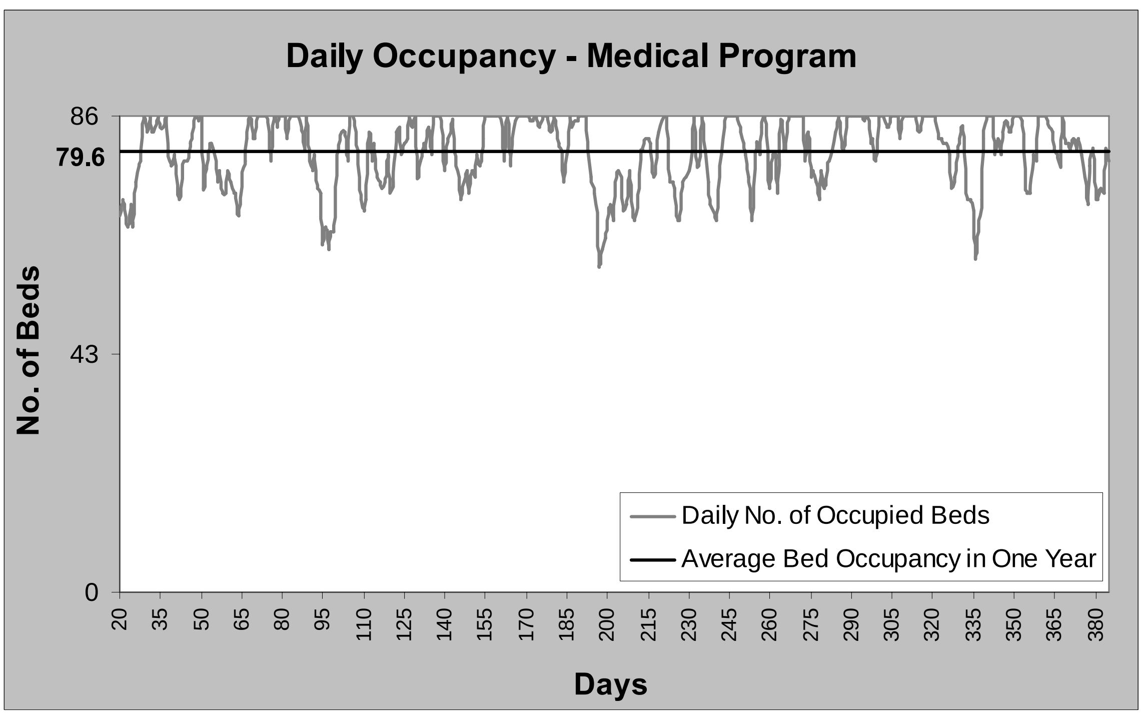
Appendix C

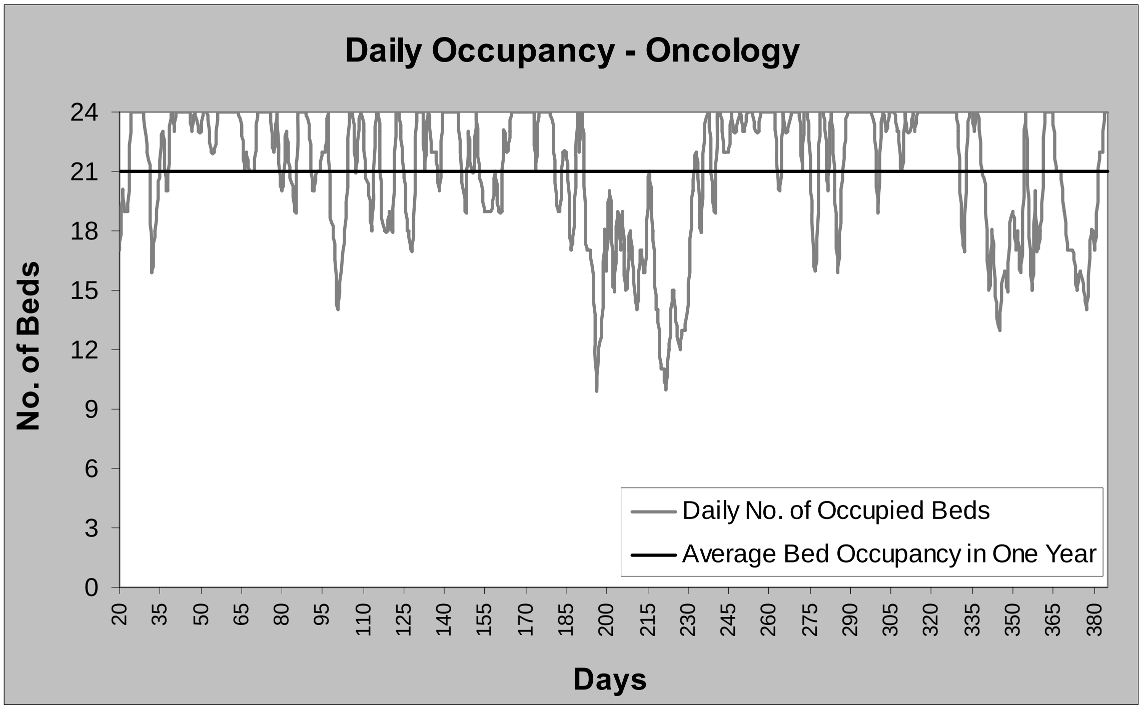
Daily Occupancy Diagrams of the Six Departments

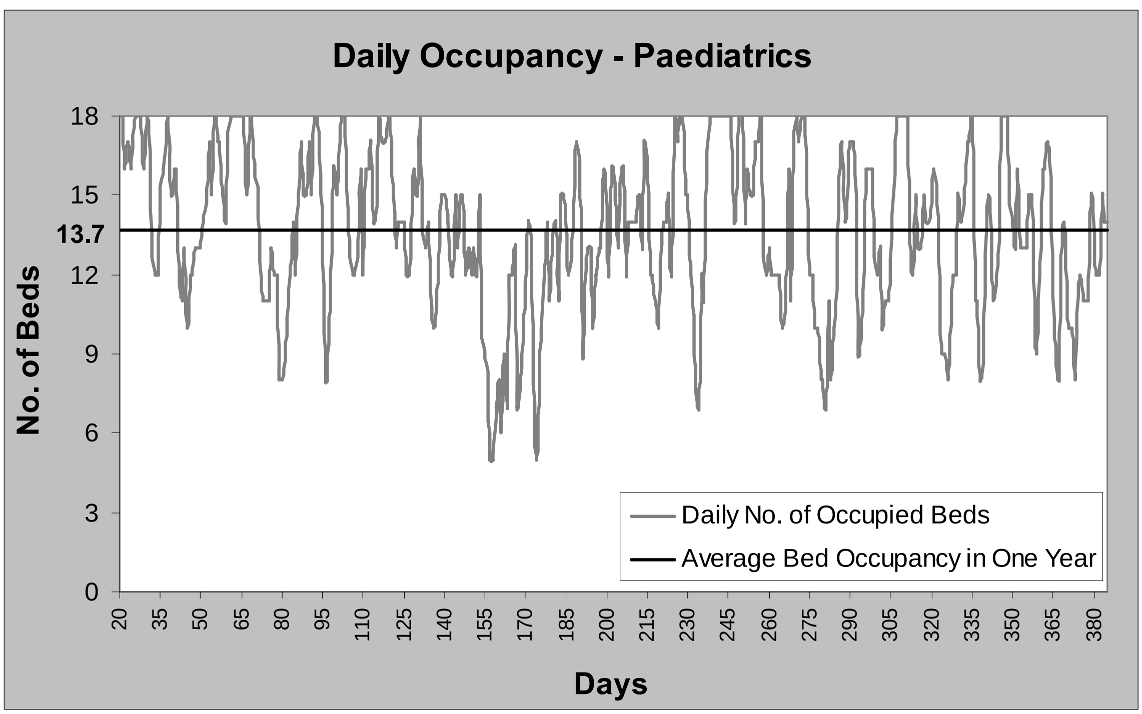

Daily Occupancy - CCU
9
7.3
6
3
0
No. of Beds
Daily No. of Occupied Beds
Average Bed Occupancy in One Year
20 35 50 65 80 95 110 125 140 155 170 185 200 215 230 245 260 275 290 305 320 335 350 365 380
Days


Daily Occupancy - General Surgery
76
67.2
57
38
19
0
No. of Beds
Daily No. of Occupied Beds
Average Bed Occupancy in One Year
20 35 50 65 80 95 110 125 140 155 170 185 200 215 230 245 260 275 290 305 320 335 350 365 380
Days


Daily Occupancy - ICU
No. of Beds
12
9.9
9
6
3
0
Daily No. of Occupied Beds
Average Bed Occupancy in One Year
20 35 50 65 80 95 110 125 140 155 170 185 200 215 230 245 260 275 290 305 320 335 350 365 380
Days


Daily Occupancy - Medical Program
No. of Beds
86
79.6
43
0
Daily No. of Occupied Beds
Average Bed Occupancy in One Year
20 35 50 65 80 95 110 125 140 155 170 185 200 215 230 245 260 275 290 305 320 335 350 365 380
Days

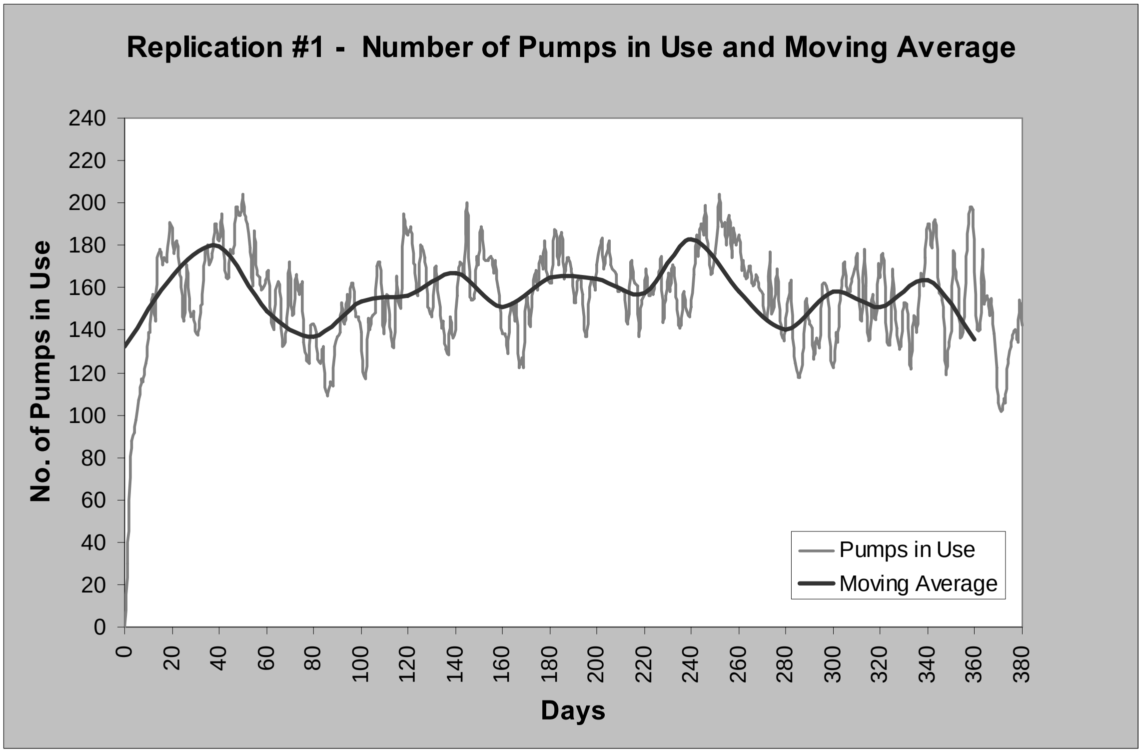

Daily Occupancy - Oncology
No. of Beds
24
21
18
15
12
9
6
3
0
Days
Daily No. of Occupied Beds
Average Bed Occupancy in One Year
20 35 50 65 80 95 110 125 140 155 170 185 200 215 230 245 260 275 290 305 320 335 350 365 380

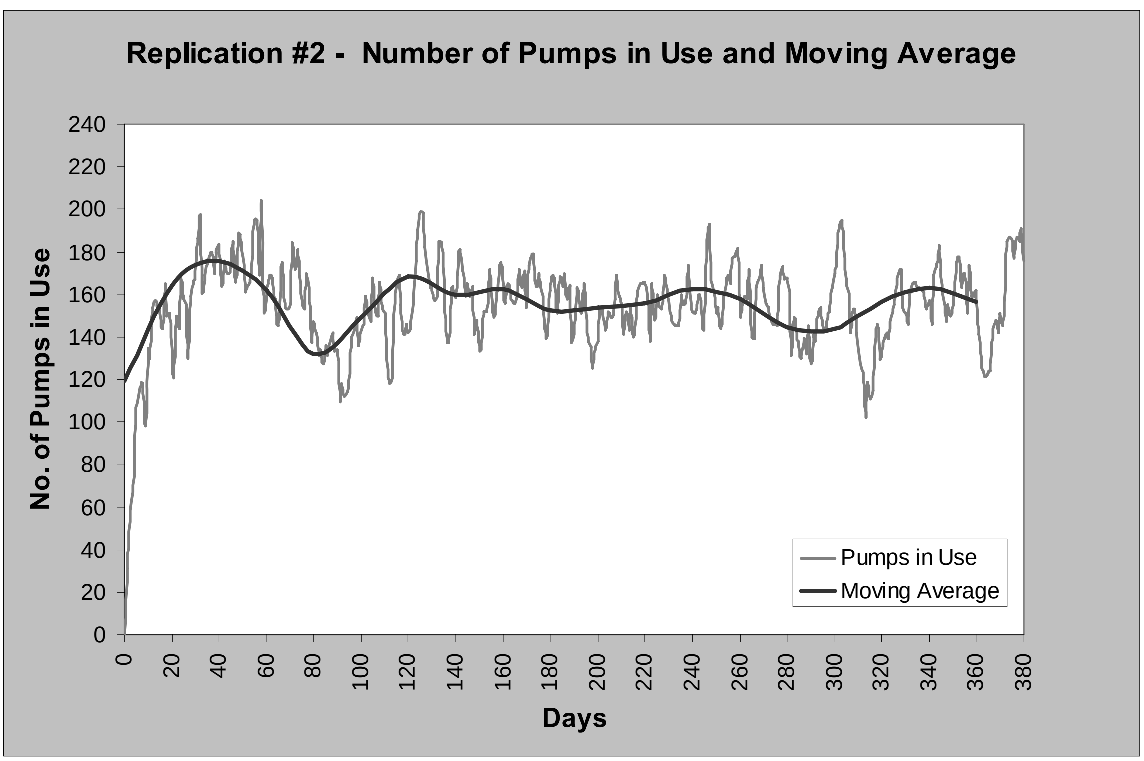

Daily Occupancy - Paediatrics
No. of Beds
18
15
13.7
12
9
6
3
0
Days
Daily No. of Occupied Beds
Average Bed Occupancy in One Year
20 35 50 65 80 95 110 125 140 155 170 185 200 215 230 245 260 275 290 305 320 335 350 365 380

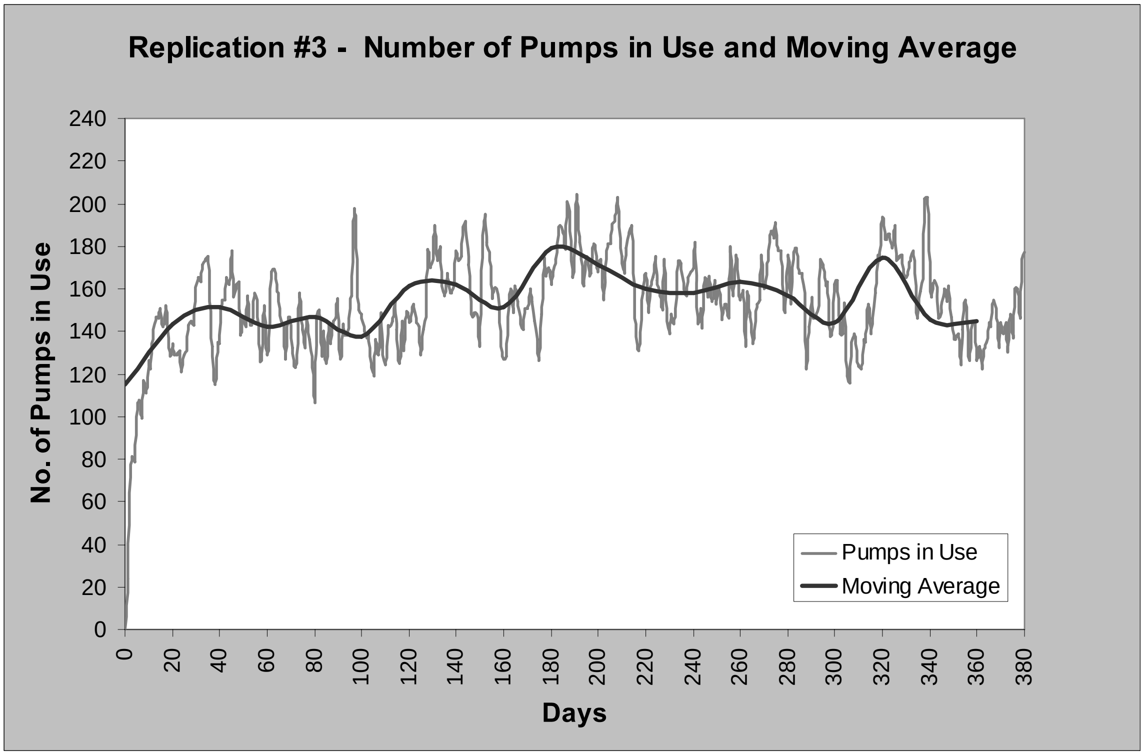
Appendix D

Daily Number of Pumps in Use and Moving Average Diagrams,

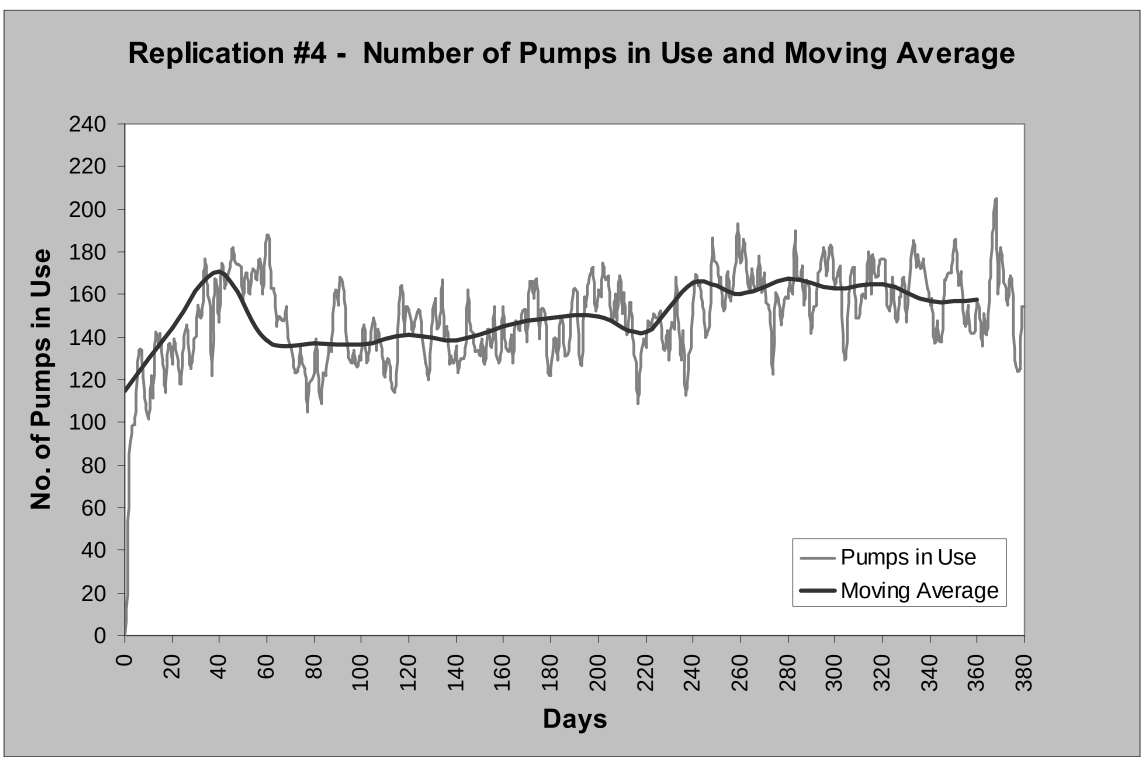
10 Replications


Replication #1 - Number of Pumps in Use and Moving Average
No. of Pumps in Use
Days
Pumps in Use
Moving Average
0
20
40
60
80
100
120
140
160
180
200
220
240
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380

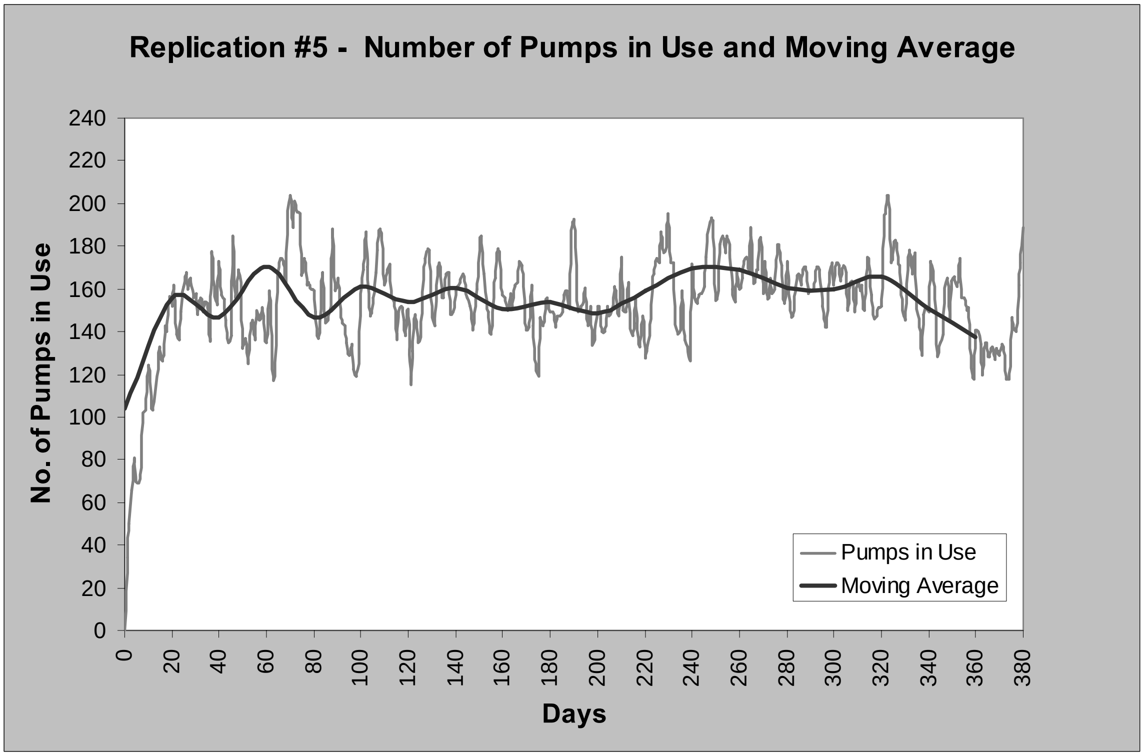

Replication #2 - Number of Pumps in Use and Moving Average
No. of Pumps in Use
Days
Pumps in Use
Moving Average
0
20
40
60
80
100
120
140
160
180
200
220
240
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380



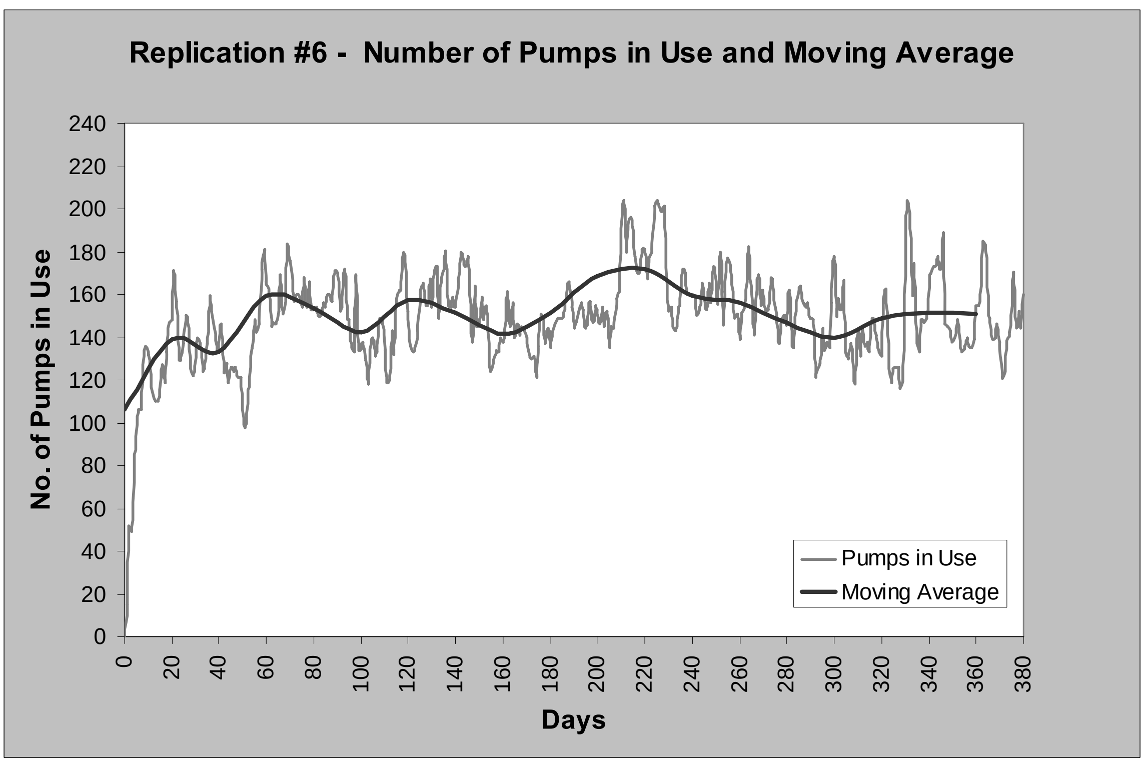
Replication #3 - Number of Pumps in Use and Moving Average
No. of Pumps in Use
Days
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
Pumps in Use
Moving Average



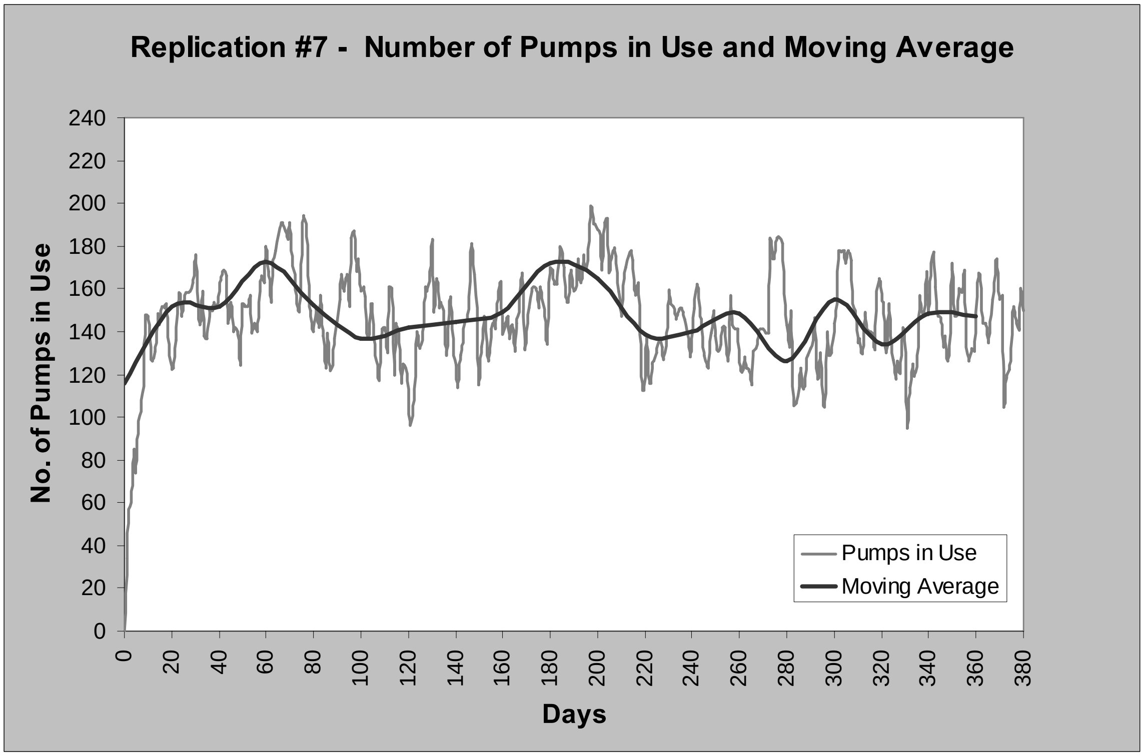
Replication #4 - Number of Pumps in Use and Moving Average
No. of Pumps in Use
Days
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
Pumps in Use
Moving Average

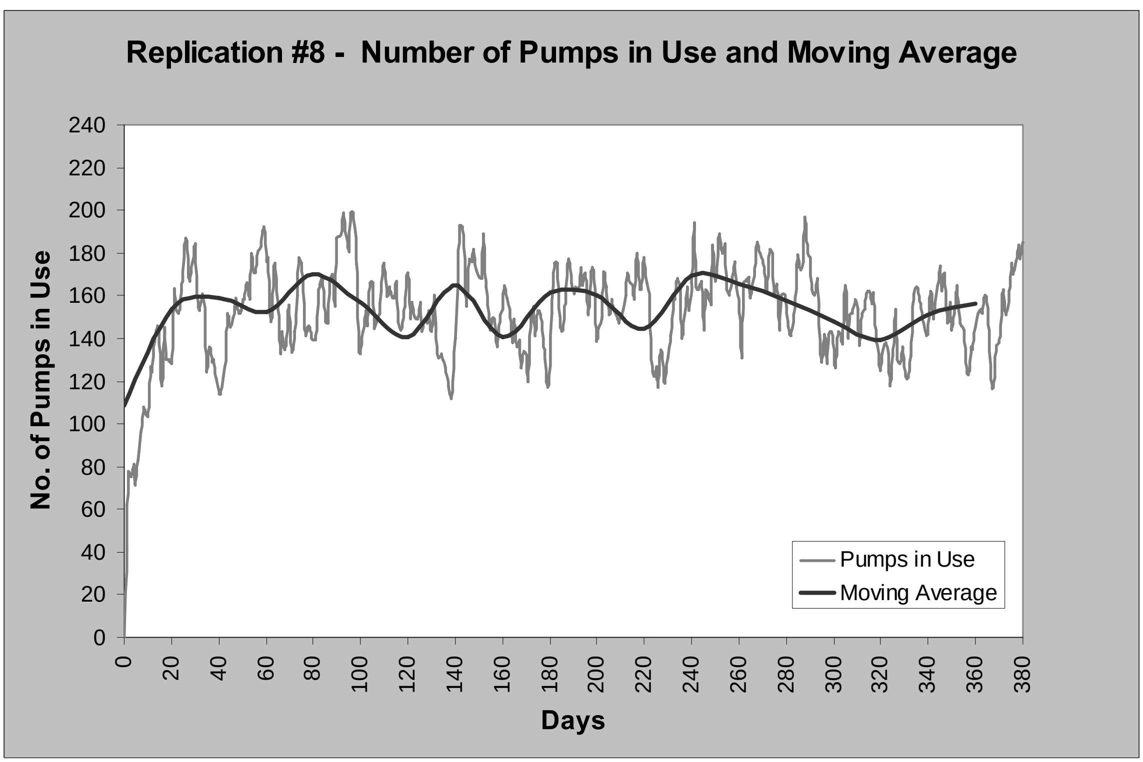


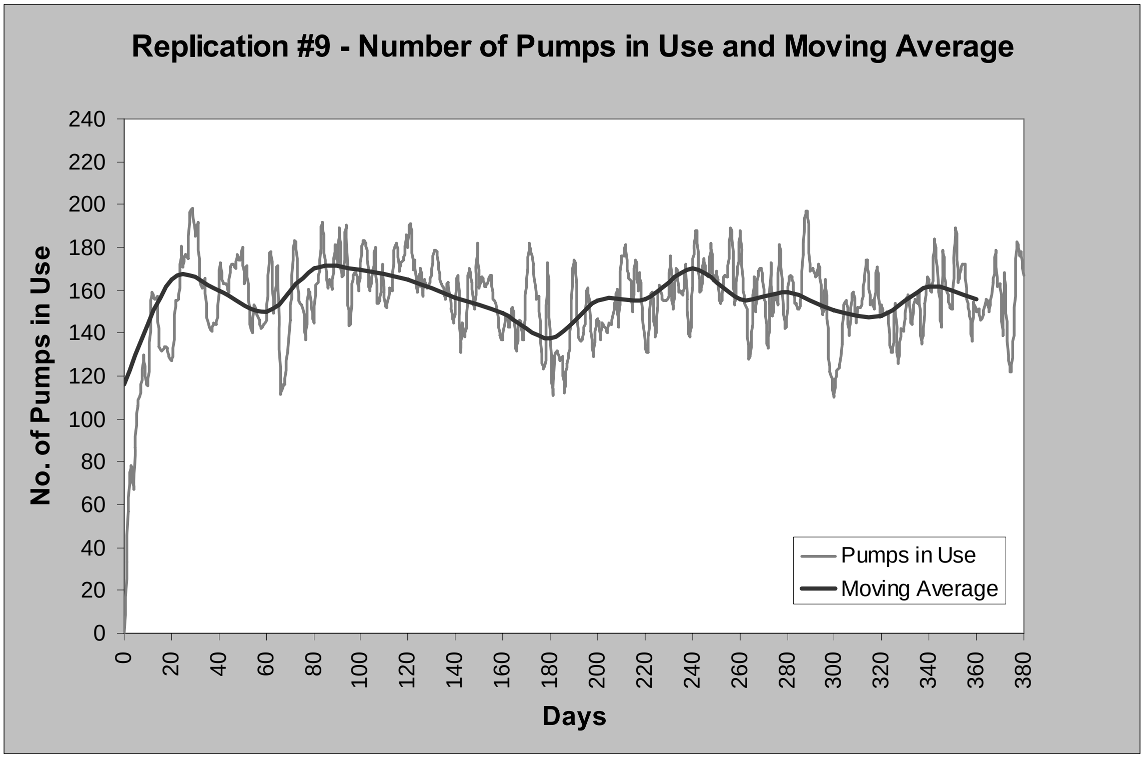
Replication #5 - Number of Pumps in Use and Moving Average
No. of Pumps in Use
0
20
40
60
80
100
120
140
160
180
200
220
240
Days
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
Pumps in Use
Moving Average

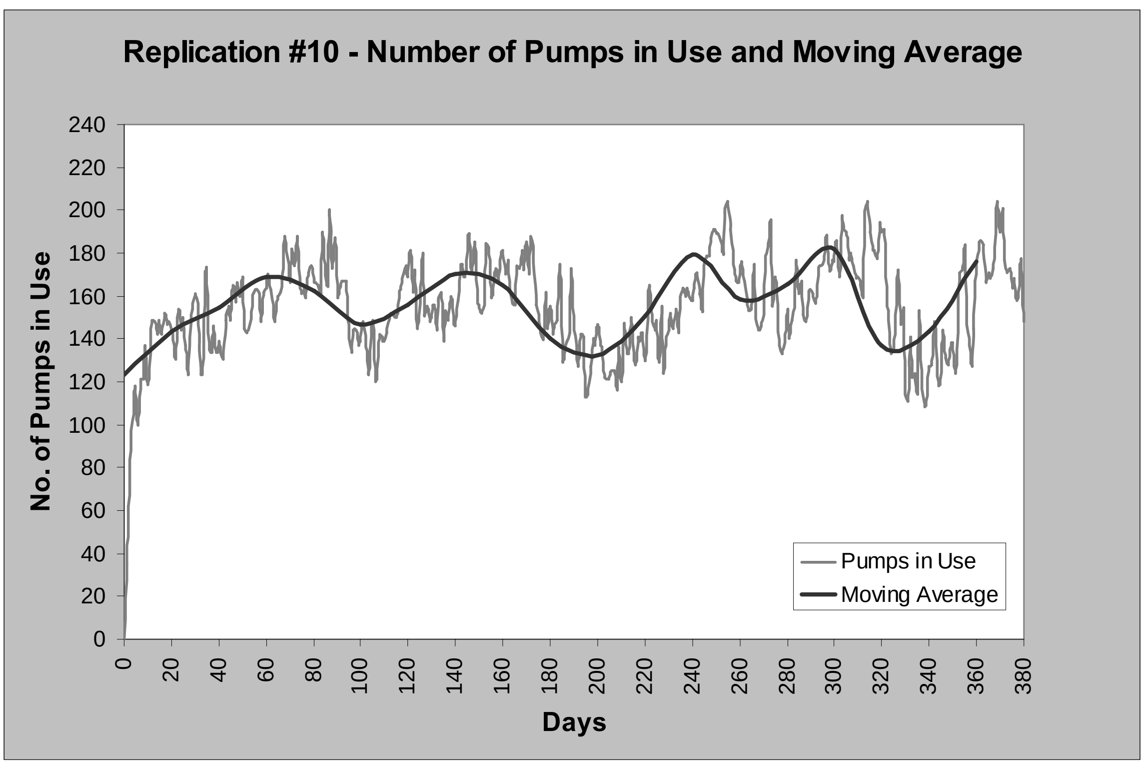


Replication #6 - Number of Pumps in Use and Moving Average
No. of Pumps in Use
0
20
40
60
80
100
120
140
160
180
200
220
240
Days
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
Pumps in Use
Moving Average


Replication #7 - Number of Pumps in Use and Moving Average
No. of Pumps in Use
0
20
40
60
80
100
120
140
160
180
200
220
240
Days
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
Pumps in Use
Moving Average


Replication #8 - Number of Pumps in Use and Moving Average
No. of Pumps in Use
0
20
40
60
80
100
120
140
160
180
200
220
240
Days
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
Pumps in Use
Moving Average


Replication #9 - Number of Pumps in Use and Moving Average
No. of Pumps in Use
Days
Pumps in Use
Moving Average
0 20 40 60 80 100 120 140 160 180 200 220 240
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380


Replication #10 - Number of Pumps in Use and Moving Average
No. of Pumps in Use
Days
Pumps in Use
Moving Average
0 20 40 60 80 100 120 140 160 180 200 220 240
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380

Appendix E

Numbers of Pumps to Maintain in Each Department to Meet Service Levels between 0% and 100%

CCU:

# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)
0	.03%	8	5.97%	16	44.36%	24	98.22%
1	.08%	9	8.49%	17	51.81%	25	99.34%
2	.33%	10	11.92%	18	59.86%	26	99.89%
3	.47%	11	16.25%	19	69.73%	27	99.95%
4	.93%	12	20.27%	20	78.90%	28	99.95%
5	1.53%	13	25.32%	21	86.66%	29	100.00%
6	2.71%	14	31.01%	22	92.33%		
7	3.95%	15	37.18%	23	95.92%		

General Surgery:

# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)
7	.03%	23	3.67%	39	52.30%	55	97.10%
8	.05%	24	4.63%	40	56.74%	56	97.84%
9	.08%	25	5.51%	41	61.23%	57	98.71%
10	.08%	26	7.04%	42	65.45%	58	99.07%
11	.11%	27	8.36%	43	69.56%	59	99.32%
12	.25%	28	10.58%	44	73.92%	60	99.48%
13	.27%	29	13.12%	45	77.48%	61	99.56%
14	.33%	30	16.16%	46	80.82%	62	99.67%
15	.47%	31	18.90%	47	84.52%	63	99.73%
16	.60%	32	22.22%	48	86.88%	64	99.78%
17	.71%	33	25.95%	49	89.10%	65	99.84%
18	.90%	34	29.92%	50	91.18%	66	99.89%
19	1.10%	35	34.47%	51	92.96%	67	99.95%
20	1.40%	36	38.49%	52	94.58%	68	99.97%
21	1.95%	37	43.59%	53	95.75%	69	99.97%
22	2.68%	38	47.64%	54	96.36%	70	100.00%

ICU:

# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)
2	.05%	22	16.77%	42	71.21%	62	98.85%
3	.08%	23	18.90%	43	73.89%	63	99.01%
4	.08%	24	21.18%	44	76.79%	64	99.21%
5	.22%	25	23.53%	45	79.15%	65	99.23%
6	.52%	26	26.03%	46	81.23%	66	99.42%
7	.88%	27	28.47%	47	83.23%	67	99.53%
8	1.42%	28	30.96%	48	85.45%	68	99.64%
9	1.62%	29	33.56%	49	86.74%	69	99.73%
10	2.00%	30	36.55%	50	88.30%	70	99.78%
11	2.74%	31	39.37%	51	89.78%	71	99.78%
12	3.48%	32	41.97%	52	91.04%	72	99.81%
13	4.08%	33	44.74%	53	92.16%	73	99.92%
14	4.93%	34	47.95%	54	93.48%	74	99.95%
15	6.03%	35	50.77%	55	94.49%	75	99.95%
16	7.23%	36	54.30%	56	95.34%	76	99.95%
17	8.63%	37	56.60%	57	96.03%	77	99.95%
18	10.00%	38	59.89%	58	96.85%	78	99.97%
19	11.51%	39	62.74%	59	97.62%	79	99.97%
20	13.18%	40	65.73%	60	98.05%	80	100.00%
21	14.88%	41	68.52%	61	98.55%		

Medical Program:

# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)
4	.08%	11	22.03%	18	85.32%	25	99.56%
5	.47%	12	30.68%	19	90.27%	26	99.70%
6	1.42%	13	40.44%	20	93.92%	27	99.86%
7	3.23%	14	50.74%	21	96.30%	28	99.97%
8	5.64%	15	61.04%	22	97.81%	29	100.00%
9	9.70%	16	70.16%	23	98.63%		
10	15.32%	17	78.90%	24	99.23%		

Oncology:

# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)
6	.05%	14	10.47%	22	71.10%	30	99.59%
7	.22%	15	14.33%	23	79.73%	31	99.75%
8	.58%	16	19.78%	24	86.88%	32	99.86%
9	.99%	17	25.78%	25	91.78%	33	99.92%
10	1.97%	18	33.04%	26	95.04%	34	100.00%
11	2.99%	19	41.84%	27	96.93%		
12	5.12%	20	51.73%	28	98.38%		
13	7.37%	21	61.75%	29	99.23%		

Paediatrics:

# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)
2	.03%	10	9.59%	18	62.19%	26	97.97%
3	.05%	11	13.62%	19	69.59%	27	98.82%
4	.16%	12	18.85%	20	76.30%	28	99.53%
5	.60%	13	24.68%	21	82.55%	29	99.73%
6	1.45%	14	31.29%	22	88.00%	30	99.81%
7	2.79%	15	39.21%	23	91.56%	31	99.92%
8	4.38%	16	46.99%	24	94.71%	32	99.95%
9	6.60%	17	54.47%	25	96.22%	33	100.00%

Appendix F

Average Number of Pumps Short per Day, by Department

CCU:

Day	Shortage	Day	Shortage	Day	Shortage	Day	Shortage	Day	Shortage	Day	Shortage
21	0.2	82	1.4	143	1.9	204	1.8	265	3.4	326	2
22	1.3	83	1.7	144	0.5	205	0.6	266	2.3	327	1.4
23	3.1	84	2.7	145	1.5	206	1.9	267	2.5	328	1.2
24	1.3	85	1.2	146	2	207	0.8	268	2.4	329	2.3
25	2.9	86	2.4	147	2.2	208	1.7	269	2.5	330	0.2
26	1.5	87	1.2	148	2.3	209	1.3	270	1.3	331	3.7
27	2	88	3.4	149	2.2	210	1.9	271	1.7	332	1.7
28	2.7	89	2	150	0.5	211	1.7	272	1.4	333	2.2
29	0.9	90	2	151	3.6	212	1.7	273	2.1	334	0.4
30	2	91	1.1	152	1.3	213	2.6	274	0.8	335	2.7
31	1	92	1.6	153	2.3	214	2.7	275	3.8	336	2
32	1.3	93	1.8	154	1.5	215	0.9	276	0.9	337	2.4
33	0.9	94	1.4	155	0.8	216	1.5	277	3.6	338	1
34	0.8	95	2.2	156	0.6	217	1	278	1	339	1.8
35	3.4	96	2.2	157	2.4	218	2.5	279	2.3	340	2
36	2.1	97	2.2	158	1.6	219	1.2	280	1.1	341	2.2
37	0.9	98	0.4	159	0.3	220	1.7	281	1.1	342	1.2
38	3.1	99	0.9	160	1.9	221	1.8	282	1.7	343	2.1
39	1.6	100	1.6	161	4.2	222	4.2	283	1.1	344	0.7
40	2.7	101	2.4	162	0.9	223	2.4	284	1.7	345	1.4
41	4	102	0.8	163	0.7	224	2.5	285	0.9	346	2.5
42	1.4	103	2.2	164	1.1	225	1.1	286	2	347	0.9
43	2.2	104	0.5	165	1.9	226	1.7	287	3.6	348	2.1
44	1.9	105	2.9	166	2.6	227	1.2	288	0.2	349	1.9
45	1.3	106	2.1	167	1.3	228	0.8	289	0.8	350	1.3
46	0.3	107	3.2	168	1.1	229	2.1	290	2.4	351	2.4
47	4.8	108	3.7	169	1.7	230	1.6	291	1.4	352	2.3
48	0.4	109	2.3	170	1.2	231	2.6	292	2	353	0.5
49	2.2	110	0.5	171	1.1	232	0.4	293	2.4	354	3.2
50	2.3	111	1.4	172	2.8	233	2.3	294	1.8	355	1.4
51	1	112	0.7	173	1.4	234	1.3	295	1.1	356	1.8
52	0.8	113	2.5	174	0.9	235	2.9	296	0.9	357	1.2
53	2.4	114	1.4	175	1.1	236	1	297	1.1	358	1.6
54	2.6	115	2.7	176	1.9	237	2.7	298	2.8	359	1.1
55	4.5	116	2.9	177	1.6	238	1.7	299	2.5	360	1.8
56	1.3	117	1.1	178	3.8	239	1	300	1.7	361	1.4
57	0.8	118	2.4	179	2.5	240	2	301	2.4	362	2
58	1.2	119	1.3	180	0.6	241	4.3	302	1.2	363	1.2
59	2.2	120	1.7	181	2.1	242	1.4	303	3.1	364	0.8
60	1.1	121	2.1	182	2	243	0.5	304	1.6	365	2.5
61	3.9	122	2.3	183	3.2	244	2	305	0.9	366	1.7
62	1.1	123	1.2	184	1.9	245	1.3	306	0.8	367	1.9
63	1	124	0.6	185	2.2	246	1.2	307	1.6	368	1.6
64	1.9	125	1.5	186	2	247	1.5	308	2.6	369	3.5
65	1	126	2	187	2.8	248	0.5	309	0.8	370	3.1
66	3.2	127	2	188	3	249	4.3	310	2.7	371	1
67	1	128	2	189	2.3	250	0.7	311	2.2	372	3.2
68	2.8	129	2.9	190	0.7	251	0.3	312	3	373	1
69	1.4	130	2.6	191	1.7	252	1.5	313	2	374	2.4
70	2	131	0.8	192	1.5	253	0.7	314	1.7	375	3.4
71	0.9	132	1.7	193	1.5	254	2.4	315	1.5	376	1.4
72	1.4	133	0.4	194	2.4	255	1.6	316	2.8	377	2.1
73	2.9	134	3.5	195	1.9	256	1.4	317	1.3	378	1.6
74	1.4	135	2.1	196	0.8	257	0.5	318	0.6	379	2.1
75	3.9	136	2.5	197	2	258	1.4	319	1.7	380	2.1
76	0.9	137	3	198	2	259	2.4	320	1.7	381	0.8
77	1	138	0.7	199	2.4	260	1.5	321	2.5	382	2.9
78	1.3	139	2.3	200	2.1	261	2.6	322	1.2	383	0.6
79	1	140	0.9	201	1.9	262	1.6	323	1.5	384	1
80	3.1	141	2.4	202	1.9	263	1.5	324	1.1	385	0.5
81	2.1	142	3.8	203	2.2	264	1.8	325	3.5		

General Surgery:

Day	Shortage	Day	Shortage	Day	Shortage	Day	Shortage	Day	Shortage	Day	Shortage
21	5.6	82	2.6	143	2.6	204	1.6	265	3.9	326	6.9
22	4	83	4.5	144	2.5	205	2.3	266	5.2	327	2.3
23	0.6	84	0.4	145	3.9	206	2.8	267	3.7	328	1.9
24	5.8	85	1.8	146	3.3	207	2.7	268	4.1	329	5.2
25	3.6	86	1.8	147	1.9	208	7.2	269	3.5	330	1.7
26	3.6	87	8.1	148	2.2	209	1.5	270	0.5	331	1.5
27	1.2	88	2.1	149	2.7	210	2.5	271	2.7	332	7.2
28	2.2	89	6	150	3.4	211	3.8	272	3.8	333	2.8
29	2.4	90	4.7	151	6	212	1.7	273	4	334	3.7
30	4.4	91	3.6	152	2.2	213	3.4	274	1.7	335	1.5
31	3.1	92	3.4	153	4.3	214	2.2	275	4.5	336	2.2
32	4.5	93	2.7	154	3.3	215	0.7	276	1.1	337	2
33	3.6	94	1.8	155	2.1	216	2.5	277	2.9	338	2.5
34	3.4	95	1.5	156	3.2	217	5.1	278	3.2	339	4.4
35	1.4	96	7.2	157	5.2	218	4.7	279	3.4	340	1.6
36	2.9	97	1.7	158	3	219	6	280	5.4	341	3
37	5.3	98	6.6	159	3.5	220	1.6	281	3.1	342	3.8
38	3	99	2.8	160	2.7	221	3.9	282	2.1	343	2.1
39	2.6	100	2.6	161	2.1	222	2.3	283	1.7	344	3.6
40	2.2	101	1.8	162	2.9	223	3.6	284	8.1	345	3.7
41	4.7	102	5.1	163	4	224	3.4	285	5	346	4
42	2.3	103	2.9	164	2.8	225	2	286	0.7	347	2.2
43	3.8	104	3.1	165	4	226	3.3	287	3.5	348	2.8
44	6.2	105	3.9	166	0.2	227	3.7	288	5.1	349	3
45	3.8	106	2.7	167	1.7	228	1.9	289	0.6	350	1.4
46	2.1	107	4	168	6.5	229	0.4	290	1	351	4.7
47	5.6	108	2.6	169	2.5	230	6.5	291	3.6	352	2.8
48	1.8	109	2.3	170	3.5	231	1.6	292	2.1	353	0.9
49	2.1	110	0.3	171	2.8	232	1.1	293	4.2	354	3.4
50	1.5	111	3.2	172	4.3	233	3.2	294	4.8	355	6.2
51	1.8	112	3.5	173	2.9	234	2.1	295	2.1	356	0.8
52	5.4	113	3.3	174	2.1	235	3.9	296	1	357	1.7
53	0.6	114	2.3	175	2.1	236	1.9	297	1.8	358	2.1
54	5.9	115	4.6	176	1.9	237	1.9	298	2.3	359	2.9
55	5.8	116	3.3	177	5.3	238	3	299	4.3	360	2
56	2.9	117	4.4	178	2.9	239	4.1	300	2.5	361	5.6
57	0	118	3.4	179	1.9	240	5.4	301	1.2	362	4.6
58	6.7	119	5.1	180	5.5	241	3	302	5.6	363	5.3
59	4.1	120	1.6	181	3.7	242	2.8	303	2.7	364	3.7
60	2.4	121	1.4	182	4.1	243	2.9	304	2.2	365	1.4
61	4.3	122	3.9	183	3	244	2.4	305	3.5	366	5.4
62	2.6	123	5	184	7	245	4.4	306	5.1	367	3.4
63	4.9	124	3.9	185	2.4	246	0.5	307	4.7	368	4
64	1.5	125	1.7	186	0.9	247	4.8	308	0.9	369	3.7
65	5	126	5.9	187	1.4	248	4.8	309	3.4	370	3.4
66	3.7	127	2.2	188	4.1	249	1.9	310	1.2	371	2.2
67	2.5	128	3.6	189	4	250	3.2	311	3.1	372	3.8
68	0.8	129	2.6	190	2.9	251	2.5	312	4	373	1.8
69	4.7	130	4.3	191	2.2	252	3.5	313	3.8	374	2.2
70	2.4	131	2	192	3	253	3.1	314	2	375	5.8
71	3.8	132	3.5	193	3	254	6.6	315	2.3	376	1.9
72	1.5	133	5.6	194	1.9	255	1.3	316	3.5	377	6.1
73	4.5	134	2.3	195	4.2	256	3.5	317	2.8	378	2.6
74	4.6	135	1.4	196	2.7	257	1.8	318	4.8	379	2.8
75	2	136	4.8	197	4.3	258	4.2	319	1.9	380	2.2
76	1.4	137	0.4	198	3.4	259	3.4	320	1.7	381	1.6
77	3.2	138	3.8	199	2.7	260	1.7	321	4.4	382	3.2
78	2.3	139	2	200	3.2	261	1.2	322	3.3	383	1.6
79	4.4	140	3.8	201	6.1	262	4.1	323	4.2	384	1.2
80	1.1	141	4.5	202	1.8	263	0	324	3.9	385	4.9
81	3.8	142	5.5	203	4.1	264	2.6	325	2		

ICU:

Day	Shortage	Day	Shortage	Day	Shortage	Day	Shortage	Day	Shortage	Day	Shortage
21	3.1	82	1.8	143	2.6	204	3.2	265	2.7	326	3.5
22	5.6	83	1	144	1.8	205	2.6	266	4.5	327	3.7
23	4.6	84	6.3	145	7.5	206	3.7	267	3.6	328	2.1
24	2.9	85	1.5	146	4	207	7.4	268	4.9	329	3
25	3.2	86	5.9	147	1.9	208	2.8	269	2.1	330	2.6
26	4.5	87	3.5	148	3.4	209	4.4	270	2.8	331	7.3
27	1.3	88	2.4	149	5.1	210	3.2	271	5.7	332	7.7
28	5.5	89	3.1	150	2	211	6.7	272	4.7	333	2.4
29	3	90	4.1	151	4.3	212	2.6	273	6.2	334	4.1
30	5.8	91	3.7	152	3.4	213	5.1	274	1.3	335	1.9
31	2.8	92	2.6	153	3.3	214	4.8	275	4.6	336	6.1
32	1.7	93	4.7	154	2.2	215	1.6	276	7.1	337	3.5
33	1.1	94	4.5	155	1.4	216	4.6	277	3.4	338	7.7
34	7.8	95	3.1	156	7.6	217	3.1	278	3.3	339	3.9
35	5.3	96	3.3	157	1.2	218	1	279	3.3	340	3.4
36	4.7	97	4.2	158	1.5	219	6.3	280	4	341	3.8
37	2.1	98	2.5	159	3.2	220	3.2	281	2.1	342	4.9
38	3.6	99	1.6	160	3.4	221	4.2	282	4.3	343	3.8
39	5.3	100	2.4	161	1.5	222	4.5	283	4.5	344	3.1
40	5.8	101	2.3	162	5.1	223	4.3	284	4.3	345	1.7
41	3.2	102	3.6	163	2.5	224	2.5	285	1.3	346	3.1
42	3.1	103	4.2	164	4.1	225	3.6	286	2	347	2.8
43	2.1	104	2	165	3.5	226	1.2	287	4.8	348	2.4
44	2.7	105	2.4	166	4	227	1.8	288	2	349	1.1
45	4.5	106	4.2	167	3.4	228	4.1	289	4.4	350	6.3
46	6.2	107	2.9	168	1.5	229	4	290	1.9	351	4.8
47	2.6	108	7.4	169	1.3	230	2.1	291	7	352	2.9
48	4.9	109	4.7	170	4.1	231	5	292	1.6	353	2.5
49	3.4	110	1.6	171	4.8	232	2.8	293	3.5	354	5.5
50	2.1	111	4.1	172	6.8	233	4.8	294	1.9	355	3
51	1.3	112	4.3	173	1.7	234	2.1	295	3.5	356	4.4
52	3.3	113	1.5	174	3	235	1.8	296	1.2	357	3.6
53	5.3	114	2.6	175	3.2	236	2.5	297	5.4	358	0.6
54	2.8	115	7.5	176	4.4	237	1.6	298	7.5	359	5.9
55	6.1	116	6.1	177	1.4	238	3	299	2.9	360	5.6
56	2.8	117	2.5	178	2.8	239	4.9	300	4.7	361	0.7
57	3.7	118	3.9	179	4.3	240	9.5	301	3.9	362	4.5
58	1.7	119	3.1	180	3.9	241	3.4	302	3.6	363	3.8
59	2.5	120	2.8	181	3.3	242	2.7	303	6.1	364	3.1
60	2	121	2.5	182	7.5	243	2.3	304	2.9	365	3.3
61	5.5	122	2	183	3	244	4.6	305	3	366	3.5
62	5.6	123	7.9	184	5.3	245	4.5	306	2.9	367	7.2
63	1.6	124	2	185	2.4	246	5.3	307	1.1	368	2.9
64	4.4	125	5.9	186	1.5	247	3.6	308	1.5	369	1.1
65	3.3	126	2.2	187	5	248	7	309	1.8	370	0.6
66	3.1	127	3.4	188	5.8	249	3.2	310	7.2	371	3.6
67	3.2	128	4	189	5.3	250	0.3	311	1.2	372	2.7
68	4.8	129	4	190	6.2	251	5.7	312	1.7	373	8.1
69	3	130	3.4	191	3.7	252	5.5	313	4.7	374	4.2
70	3.6	131	4.8	192	0.5	253	4.1	314	10	375	3.4
71	2.8	132	5.1	193	2.5	254	2.6	315	1.1	376	1.3
72	4.6	133	5.2	194	4.5	255	4.5	316	8	377	5.9
73	3.5	134	5.3	195	2.2	256	6.6	317	0.4	378	3.9
74	3	135	2.6	196	4.7	257	2.3	318	5.5	379	5.1
75	4	136	3.3	197	3.9	258	3.9	319	2.6	380	5.3
76	3.7	137	0.9	198	5.1	259	1.4	320	2.7	381	1.6
77	0.6	138	5.2	199	2.9	260	5.7	321	6.2	382	4.9
78	5.1	139	2.9	200	1.4	261	1.3	322	4.6	383	2.5
79	1.3	140	5.9	201	3	262	3.8	323	2.6	384	2.3
80	5.7	141	5	202	3.4	263	7.7	324	1.3	385	2.6
81	6.3	142	6.6	203	3.4	264	3.1	325	2.1		

Medical Program:

Day	Shortage	Day	Shortage	Day	Shortage	Day	Shortage	Day	Shortage	Day	Shortage
21	0	82	0.9	143	3.2	204	0.6	265	1.1	326	2.9
22	2.3	83	1.9	144	0.2	205	1.7	266	1.7	327	0.6
23	1.5	84	1.6	145	1.2	206	2.6	267	1.1	328	1.3
24	0.8	85	2.8	146	2.3	207	1.7	268	0.6	329	0.7
25	2.5	86	1.1	147	1.5	208	0.6	269	2.4	330	2
26	1.4	87	1.2	148	1.5	209	2	270	0	331	1.8
27	1.3	88	1	149	0.9	210	1.2	271	2.3	332	1.3
28	1	89	1.9	150	2.7	211	2.1	272	1.1	333	1.1
29	2.5	90	1	151	2.6	212	2.1	273	0.5	334	2.3
30	1.7	91	0.9	152	1	213	2.1	274	3.1	335	0.9
31	3.6	92	2.2	153	1.9	214	0.8	275	1	336	0.3
32	1.3	93	2.1	154	0.9	215	2.4	276	1.4	337	2.2
33	1.1	94	0.9	155	2.5	216	1.8	277	2.7	338	0.7
34	1.1	95	0.8	156	0.6	217	1.8	278	1.2	339	0.9
35	1.9	96	0.9	157	0.3	218	2.2	279	1.1	340	3.4
36	1.2	97	2.2	158	1.9	219	1.8	280	1.3	341	1.9
37	1.6	98	2.4	159	1.6	220	0.6	281	2	342	2.4
38	1.1	99	1.3	160	2	221	1.6	282	2.5	343	0.2
39	1.5	100	3	161	1.8	222	2	283	1.2	344	0.9
40	2.3	101	0.6	162	1.2	223	1.5	284	2	345	2.4
41	1.4	102	0.8	163	1.3	224	1	285	0.8	346	1.4
42	1.4	103	2.2	164	1.4	225	2.1	286	1.3	347	1.5
43	2.9	104	1.5	165	1.4	226	1	287	1.6	348	2
44	1.6	105	1	166	0.8	227	0.8	288	1.6	349	0.5
45	1.6	106	2.2	167	0.8	228	2.6	289	1.7	350	1.8
46	1	107	1.8	168	1.2	229	1.1	290	2.2	351	1.5
47	1.2	108	0.4	169	4.2	230	1.1	291	0.8	352	1.7
48	1.2	109	2.2	170	1.4	231	1	292	1.6	353	1.1
49	1.6	110	0.5	171	1.1	232	2.6	293	2.6	354	2.6
50	1.5	111	2.3	172	1.8	233	1.1	294	1.6	355	2.4
51	1.9	112	1.4	173	2.3	234	1.8	295	1.7	356	1
52	1.4	113	1.1	174	1.4	235	1.5	296	1.1	357	2.9
53	2.2	114	1.8	175	1.9	236	2.6	297	1.5	358	1.9
54	1.9	115	1.4	176	0.6	237	1.6	298	4.5	359	0.3
55	1.1	116	1.4	177	1.1	238	1.9	299	2	360	1.5
56	2	117	2.4	178	0.4	239	0.8	300	1.7	361	1.6
57	2.1	118	1.8	179	2.2	240	0.7	301	1.2	362	1.1
58	1.6	119	2.6	180	1.2	241	1.3	302	0.9	363	1.2
59	1.5	120	0.9	181	3.4	242	3.2	303	1.3	364	1.3
60	1.4	121	1.6	182	1.5	243	0.2	304	0.5	365	0.6
61	0.8	122	2.2	183	1.4	244	1.2	305	1.9	366	1.1
62	2.1	123	1.6	184	0.7	245	2.8	306	3	367	3.3
63	0.1	124	2.3	185	3.6	246	1.6	307	0.3	368	2.4
64	3.1	125	0.4	186	1.2	247	1.5	308	1.3	369	0.8
65	1.2	126	1.9	187	2.1	248	2.8	309	1.9	370	2.1
66	0.4	127	1.8	188	2.5	249	1.1	310	1	371	0.8
67	2.3	128	1.6	189	0.5	250	3.3	311	2	372	1.4
68	1.7	129	2.9	190	1.4	251	0.5	312	0.5	373	0.9
69	1.5	130	1.5	191	1.2	252	0.5	313	2.4	374	1
70	1.1	131	0.6	192	0.9	253	2.5	314	1.4	375	1.7
71	1.1	132	1.3	193	1	254	0.6	315	1.3	376	1.8
72	2.7	133	2.8	194	2.6	255	2.9	316	0.5	377	1.2
73	0.4	134	2	195	1.4	256	2.6	317	1.8	378	2.1
74	2.2	135	1.1	196	2.5	257	1.1	318	1.7	379	1.5
75	1.9	136	1	197	0.4	258	1.2	319	1.1	380	0.7
76	1.2	137	0.9	198	1.5	259	1.6	320	4.4	381	0.7
77	1.5	138	2.2	199	1.3	260	1.8	321	1.1	382	2.8
78	0.6	139	2.9	200	1.5	261	0.4	322	3.1	383	0.3
79	2	140	0.2	201	1.8	262	1.8	323	3.3	384	2
80	1.1	141	2.9	202	2.1	263	1.8	324	2.9	385	0.7
81	1.6	142	2.9	203	0.8	264	1.8	325	0.5		

Oncology:

Day	Shortage	Day	Shortage	Day	Shortage	Day	Shortage	Day	Shortage	Day	Shortage
21	2.7	82	1	143	1.3	204	2.3	265	1	326	1.5
22	0.7	83	1.9	144	1.7	205	0.9	266	1.3	327	0.2
23	1.5	84	1.7	145	0	206	1.6	267	1.1	328	1.3
24	1.5	85	1.1	146	0.8	207	0.5	268	0.6	329	1
25	2.5	86	0.9	147	0.7	208	1.9	269	2	330	0.8
26	0.3	87	1.4	148	0.5	209	1.6	270	2.5	331	0.7
27	2.1	88	1	149	2.3	210	1.1	271	1.7	332	1.3
28	1.7	89	0.4	150	0.6	211	0.5	272	1.2	333	1.4
29	1.5	90	0.4	151	1	212	1.4	273	1.1	334	1.2
30	0.6	91	2.3	152	2.3	213	0.6	274	1.7	335	1.1
31	0.8	92	0.6	153	0.5	214	1	275	1.4	336	1.5
32	1.3	93	0.5	154	0.8	215	1.2	276	0.5	337	1.6
33	2.8	94	0.7	155	1	216	1.1	277	2	338	0.6
34	1.9	95	0.7	156	0.9	217	1.9	278	1.1	339	1.3
35	0.2	96	1.7	157	0.3	218	0	279	1.1	340	0.4
36	0.6	97	1.5	158	1.4	219	1.7	280	0.7	341	2.3
37	0.3	98	1.1	159	1.6	220	1.1	281	0.6	342	0.5
38	0.4	99	0.7	160	0.6	221	0.9	282	0.3	343	1.4
39	2.9	100	1.1	161	0.7	222	0.8	283	2.4	344	0.4
40	1	101	2.2	162	1.2	223	2.4	284	1.1	345	1.3
41	1	102	1.1	163	0.5	224	2.3	285	1.4	346	0.7
42	1	103	0.5	164	2.2	225	0.7	286	1.6	347	0.7
43	1.6	104	1.3	165	1.4	226	1.5	287	0.9	348	1.2
44	1.8	105	1.8	166	2	227	0.4	288	1.4	349	1.8
45	1.4	106	1.1	167	1.2	228	0.9	289	1	350	1.4
46	2.6	107	0.8	168	1	229	1.1	290	1.3	351	0.9
47	1.1	108	1.9	169	0.5	230	1.8	291	0.7	352	1.6
48	1.4	109	0.4	170	1	231	2.2	292	1.1	353	0.3
49	1.1	110	1.1	171	1.6	232	1	293	0.5	354	1
50	0.8	111	0.4	172	1.5	233	0.6	294	2.5	355	0.9
51	1.6	112	1.1	173	1.1	234	1.6	295	0.7	356	1.3
52	0.6	113	0.7	174	1.2	235	0.6	296	2.5	357	0.8
53	0.6	114	0.6	175	1.8	236	2.8	297	0.8	358	1.1
54	1.4	115	2.5	176	1.9	237	0.9	298	0.4	359	1.6
55	1.9	116	1	177	0.2	238	0.4	299	1.2	360	1.1
56	1.5	117	0.9	178	0.8	239	0.5	300	1.1	361	1.7
57	0.4	118	0.2	179	0.8	240	0.5	301	0.9	362	0.9
58	0.8	119	1.3	180	1.5	241	1.9	302	0.5	363	0.6
59	1.8	120	1.1	181	1	242	0.4	303	1.1	364	1.7
60	0.9	121	1.1	182	0.1	243	0.3	304	1.3	365	1.3
61	1.1	122	1.6	183	1.9	244	0.5	305	2	366	0.4
62	0.9	123	4.2	184	0.7	245	1	306	1.3	367	1.7
63	0.8	124	0.7	185	1	246	1.3	307	1.2	368	1.6
64	0.2	125	0.4	186	1.1	247	0.7	308	1	369	0.5
65	2.4	126	1	187	1.3	248	0.9	309	0.5	370	2.1
66	0.4	127	1.3	188	0.5	249	1.4	310	0.9	371	1.3
67	1.4	128	0.6	189	1.3	250	0.4	311	1.4	372	1
68	0.8	129	1.1	190	1.2	251	0.9	312	1.1	373	0.7
69	0.8	130	1.1	191	0.8	252	1.8	313	1.6	374	1.1
70	1.4	131	1.3	192	0.8	253	1.8	314	1.1	375	1.6
71	0.5	132	0.1	193	1.2	254	1.5	315	0.5	376	0.5
72	1	133	1.8	194	1	255	1.7	316	2.1	377	0.9
73	1.4	134	1.8	195	1	256	0.6	317	0.6	378	1.8
74	1.1	135	1.1	196	1.3	257	0.3	318	1.6	379	1.3
75	1	136	1	197	1.4	258	0.2	319	1.6	380	0.9
76	0.9	137	2	198	0.3	259	1.5	320	1.1	381	1.3
77	0.8	138	0.9	199	1.8	260	0.5	321	1.1	382	2
78	2.1	139	2.3	200	0.6	261	0.8	322	2	383	1
79	0.5	140	1	201	1.1	262	1.5	323	0.1	384	0.4
80	0.6	141	1.2	202	0.7	263	2	324	3.1	385	0.5
81	1.4	142	2.4	203	0.7	264	0.8	325	1.3		

Paediatrics:

Day	Shortage	Day	Shortage	Day	Shortage	Day	Shortage	Day	Shortage	Day	Shortage
21	1.4	82	1.1	143	1.5	204	1.6	265	0.2	326	1
22	0.9	83	3.4	144	5.1	205	2.8	266	1.7	327	0.5
23	1.4	84	2.8	145	1	206	1.9	267	2.8	328	1.4
24	3.1	85	0.8	146	1	207	0.7	268	1.9	329	1.7
25	4.4	86	1.3	147	0.9	208	1.1	269	2.4	330	2.3
26	2.7	87	1.1	148	0.9	209	1.2	270	2	331	1.4
27	2.2	88	1.9	149	1.9	210	1.1	271	1.7	332	1.9
28	1.4	89	2.9	150	2	211	0.5	272	0.8	333	1.2
29	1.6	90	1.5	151	1.4	212	1.4	273	1.9	334	2.4
30	1	91	1	152	1.3	213	2.4	274	2.3	335	1
31	0.8	92	2.2	153	3.3	214	1.8	275	1.6	336	3.8
32	2.2	93	2.4	154	1.1	215	0.8	276	0.6	337	1.8
33	1.4	94	1.3	155	0.6	216	2.2	277	2.7	338	0.8
34	2.8	95	2.2	156	1.6	217	2.4	278	0.4	339	1.4
35	1	96	0.6	157	1.3	218	0.2	279	0.9	340	1.8
36	1.8	97	2.7	158	2.2	219	1.4	280	1.4	341	2.7
37	0.6	98	0.3	159	1.3	220	1	281	1.6	342	2.1
38	3	99	2.8	160	2.4	221	2.2	282	1.2	343	0.8
39	2.3	100	2	161	1	222	2	283	1.4	344	1.5
40	1.9	101	1.1	162	2.8	223	2	284	2.4	345	3.2
41	2.3	102	1.6	163	0.5	224	1.5	285	1.4	346	1.5
42	1.4	103	1	164	1.3	225	2.2	286	2.4	347	1.4
43	1.7	104	0.5	165	2.1	226	1.9	287	2.6	348	1.7
44	2.6	105	1.9	166	2	227	1.8	288	1.2	349	1.3
45	0.7	106	3	167	0.8	228	0.3	289	2.2	350	2.8
46	1.4	107	1.3	168	1	229	2.1	290	2.5	351	1
47	1.6	108	1.2	169	1.6	230	1.9	291	1.3	352	3.7
48	0.4	109	1.5	170	1.6	231	1.1	292	0.9	353	0.3
49	1.5	110	0.7	171	3.9	232	2.5	293	1.3	354	1.2
50	2.1	111	3.5	172	1.2	233	1.7	294	1.2	355	1
51	1.8	112	1.5	173	0.8	234	0.9	295	2.7	356	0.6
52	1.3	113	1.7	174	4.1	235	2	296	2.6	357	1.6
53	0.2	114	0.7	175	2.4	236	0.8	297	1.4	358	2
54	2	115	2.9	176	2.6	237	2.4	298	1.6	359	0.7
55	3.4	116	1.5	177	0.5	238	2.8	299	0.6	360	2.2
56	1.4	117	2.3	178	1.5	239	1	300	1	361	2
57	1.6	118	2.5	179	1.3	240	1.2	301	2	362	1.8
58	0.8	119	1.6	180	2	241	0.5	302	1.2	363	0.4
59	1.8	120	2.1	181	1.5	242	1.8	303	3.9	364	1
60	3.2	121	1.4	182	0.6	243	2	304	0.6	365	4.4
61	2.4	122	1.1	183	3.2	244	1.4	305	2.3	366	1.2
62	0.6	123	1.4	184	2.1	245	1	306	1.7	367	2.2
63	0.4	124	1.7	185	2	246	3.4	307	0.4	368	4.3
64	1.6	125	1	186	0.5	247	0.6	308	1.5	369	0.7
65	4.2	126	3.5	187	3.1	248	1.9	309	1.7	370	0.2
66	2.2	127	1.7	188	2.4	249	1.1	310	2.7	371	0.9
67	1.2	128	1.4	189	0.9	250	0.8	311	1.9	372	1.8
68	1.9	129	2.1	190	1.7	251	2.9	312	1.4	373	1.9
69	2.5	130	1.9	191	3.1	252	3.1	313	0.7	374	2.2
70	1.1	131	2.3	192	2.8	253	0.8	314	1.7	375	1.9
71	2.3	132	0.8	193	1.1	254	2.1	315	1.2	376	1.9
72	1.9	133	0.8	194	1.4	255	1.3	316	1.7	377	0.5
73	1.7	134	0.9	195	0.8	256	0.2	317	1.2	378	2
74	2.3	135	1.5	196	1.7	257	1.9	318	3.5	379	5.8
75	0.9	136	2	197	1.3	258	0.9	319	0.8	380	1.2
76	1.6	137	2.5	198	0.9	259	3.9	320	0.9	381	2.6
77	1.7	138	1.5	199	2.4	260	1.1	321	1.2	382	2.1
78	0.9	139	2	200	2.1	261	2.8	322	1.6	383	1.2
79	1.1	140	2	201	1.2	262	0.8	323	1.5	384	1.3
80	0.9	141	1.5	202	2.9	263	0.1	324	0.5	385	0.9
81	2.9	142	1.8	203	0.7	264	3.8	325	2.9		

Emergency:

Day	Shortage	Day	Shortage	Day	Shortage	Day	Shortage	Day	Shortage	Day	Shortage
21	12.8	82	11.8	143	12.6	204	13.6	265	12.3	326	9.2
22	11.5	83	11.4	144	11.7	205	13.3	266	12.2	327	12.1
23	11.7	84	13.9	145	14.4	206	13.0	267	12.3	328	11.2
24	12.8	85	10.7	146	12.2	207	13.3	268	13.8	329	13.0
25	10.5	86	12.7	147	13.1	208	11.9	269	12.5	330	13.4
26	13.6	87	12.1	148	14.1	209	10.8	270	13.9	331	14.4
27	12.6	88	13.3	149	12.9	210	12.4	271	11.0	332	11.2
28	11.9	89	12.5	150	11.9	211	12.0	272	11.5	333	12.5
29	13.8	90	12.3	151	11.5	212	12.8	273	15.4	334	11.5
30	15.2	91	13.4	152	13.3	213	11.1	274	12.6	335	12.0
31	14.9	92	15.2	153	10.9	214	12.7	275	12.1	336	13.9
32	12.2	93	11.6	154	12.6	215	12.2	276	13.4	337	11.4
33	13.4	94	11.3	155	11.5	216	11.6	277	11.1	338	12.5
34	12.8	95	10.0	156	11.4	217	10.3	278	14.6	339	14.1
35	11.9	96	12.3	157	14.3	218	13.7	279	13.3	340	11.2
36	11.5	97	14.5	158	13.1	219	10.1	280	14.2	341	11.4
37	12.7	98	12.3	159	14.0	220	13.9	281	10.9	342	11.7
38	13.7	99	12.2	160	12.8	221	13.1	282	12.2	343	13.5
39	12.9	100	10.9	161	12.1	222	12.3	283	16.5	344	12.9
40	12.6	101	13.9	162	10.8	223	14.2	284	10.9	345	10.9
41	12.3	102	13.3	163	12.9	224	12.8	285	10.7	346	14.0
42	13.5	103	10.3	164	13.6	225	14.9	286	12.1	347	13.3
43	12.9	104	12.4	165	11.7	226	13.5	287	11.2	348	10.6
44	11.7	105	14.7	166	10.8	227	14.1	288	11.6	349	13.8
45	13.3	106	12.3	167	12.7	228	12.1	289	12.1	350	12.8
46	15.9	107	11.9	168	12.4	229	13.2	290	12.5	351	13.5
47	12.1	108	12.0	169	12.1	230	11.1	291	12.7	352	12.6
48	13.9	109	11.0	170	12.6	231	12.4	292	12.7	353	14.6
49	11.1	110	13.3	171	15.2	232	11.1	293	12.4	354	13.4
50	13.6	111	11.2	172	13.4	233	12.7	294	12.9	355	11.2
51	12.3	112	10.9	173	13.6	234	11.4	295	11.6	356	13.2
52	13.6	113	11.4	174	11.5	235	12.6	296	12.8	357	11.5
53	13.9	114	14.5	175	10.8	236	14.5	297	14.9	358	11.3
54	13.4	115	12.1	176	12.0	237	13.0	298	13.4	359	12.5
55	11.6	116	11.5	177	12.2	238	13.1	299	13.1	360	11.9
56	11.2	117	13.6	178	13.4	239	11.5	300	13.0	361	12.0
57	11.6	118	12.7	179	12.5	240	12.3	301	14.1	362	11.3
58	13.6	119	13.1	180	12.2	241	13.2	302	15.1	363	10.6
59	12.6	120	12.4	181	11.2	242	11.4	303	11.0	364	12.9
60	13.3	121	12.0	182	14.5	243	12.7	304	13.8	365	12.2
61	12.6	122	13.2	183	13.0	244	12.3	305	12.8	366	13.2
62	10.8	123	10.8	184	14.5	245	10.5	306	9.1	367	13.3
63	12.5	124	10.7	185	12.3	246	12.4	307	11.7	368	10.2
64	13.0	125	15.1	186	15.4	247	13.0	308	14.5	369	11.9
65	11.1	126	13.3	187	13.2	248	12.1	309	12.4	370	13.6
66	12.6	127	14.3	188	11.7	249	12.8	310	14.3	371	11.3
67	13.4	128	13.9	189	12.8	250	11.8	311	11.2	372	12.4
68	10.6	129	11.1	190	12.3	251	12.8	312	12.8	373	11.4
69	12.8	130	11.0	191	11.9	252	13.3	313	12.0	374	14.5
70	14.2	131	12.6	192	11.7	253	12.3	314	13.8	375	12.3
71	13.9	132	13.9	193	13.6	254	13.3	315	12.7	376	13.5
72	13.2	133	13.6	194	14.6	255	10.8	316	12.0	377	14.4
73	13.9	134	12.9	195	13.0	256	13.1	317	13.1	378	12.8
74	14.3	135	12.7	196	12.0	257	11.6	318	12.0	379	12.4
75	12.4	136	13.4	197	13.1	258	14.0	319	14.6	380	12.6
76	12.0	137	13.3	198	14.1	259	12.1	320	12.2	381	14.7
77	11.2	138	12.9	199	12.3	260	11.6	321	13.1	382	12.4
78	13.5	139	11.5	200	13.9	261	13.8	322	12.9	383	12.8
79	12.6	140	13.0	201	12.2	262	12.1	323	12.2	384	11.7
80	12.2	141	13.7	202	11.9	263	14.9	324	10.5	385	12.8
81	11.5	142	12.0	203	12.7	264	12.3	325	11.9		

Appendix G

Average Number of Pumps in Excess per Day, by Department

CCU:

Day	Excess	Day	Excess	Day	Excess	Day	Excess	Day	Excess	Day	Excess
21	3	82	1.2	143	1	204	0.7	265	1.9	326	1.7
22	1.5	83	1.7	144	2.5	205	1.9	266	2.3	327	1.6
23	2.3	84	0.5	145	1.9	206	2.1	267	3.7	328	1.1
24	1.1	85	1.9	146	1.6	207	1.5	268	1.1	329	1.6
25	1.3	86	0.9	147	2.8	208	1.7	269	1.4	330	2.7
26	2.2	87	4.2	148	0.4	209	1.8	270	2.2	331	0.7
27	1.4	88	0.3	149	1.8	210	1	271	1.9	332	1.6
28	0.7	89	2	150	3.6	211	0.8	272	2.4	333	0.7
29	2.6	90	2.4	151	0.7	212	2.3	273	2.1	334	4
30	1.5	91	1.9	152	1.1	213	0.5	274	0.7	335	2.3
31	0.6	92	2.4	153	0.9	214	2	275	0.9	336	1.1
32	0.8	93	1.8	154	1.3	215	1.9	276	3	337	1.9
33	1.7	94	1.5	155	2	216	3.5	277	2.1	338	0.8
34	4.1	95	2	156	3.7	217	3.4	278	2.1	339	1.4
35	0.8	96	1.4	157	0.5	218	1.4	279	2.2	340	2.1
36	1.3	97	2.5	158	1.4	219	2.4	280	1	341	0.4
37	4	98	2.3	159	2.6	220	2.8	281	1.9	342	1.6
38	2.7	99	2.2	160	2.5	221	1.7	282	1.3	343	0.9
39	1.4	100	0.2	161	0.2	222	1.9	283	1.4	344	4.3
40	3.7	101	2.2	162	2.7	223	3.1	284	0.8	345	2.8
41	1.6	102	1.2	163	2.6	224	0.3	285	2.6	346	0.6
42	3.3	103	1.6	164	1.7	225	1.6	286	1.3	347	2.5
43	1.2	104	2.1	165	0.1	226	0.2	287	0.4	348	2
44	2.8	105	1.3	166	1	227	1.2	288	2.7	349	3
45	2.6	106	2.4	167	1.1	228	2.5	289	2.2	350	1.4
46	2.2	107	3.2	168	2.4	229	1.2	290	2.3	351	0.8
47	0.1	108	2	169	2.4	230	2	291	2.2	352	1.5
48	1.5	109	0.3	170	1.7	231	2.7	292	2.2	353	2
49	0.8	110	1.1	171	2.3	232	1.3	293	2.4	354	0.3
50	1.3	111	3.5	172	1.3	233	0.8	294	0.8	355	1.3
51	1.4	112	1	173	1.4	234	1.8	295	1.1	356	1.5
52	3.2	113	0.8	174	2.5	235	0.8	296	1.6	357	2.7
53	2.8	114	3.9	175	1.7	236	2.5	297	2.8	358	0.7
54	1.3	115	1.7	176	0.4	237	0.6	298	0.8	359	2
55	1.2	116	0.6	177	2.2	238	2.6	299	1.5	360	0.5
56	1.8	117	3.3	178	0.9	239	3.4	300	1.2	361	1.1
57	1.7	118	1.1	179	0.9	240	2.5	301	0.7	362	2
58	1.6	119	1.7	180	3.1	241	0.5	302	2.2	363	1.8
59	1.3	120	2.2	181	2.2	242	1.3	303	1.4	364	2.8
60	2.2	121	0.9	182	1.7	243	3.2	304	1.8	365	2.4
61	0.6	122	1.7	183	3	244	1.8	305	2.3	366	2.1
62	2.1	123	2.5	184	1.9	245	1.8	306	2.1	367	1
63	3.1	124	2.4	185	3.2	246	1.4	307	1.7	368	3.6
64	1.3	125	1.7	186	2.3	247	1.1	308	1.2	369	1.6
65	3.4	126	1.4	187	1.5	248	2.8	309	4.1	370	2.4
66	2.8	127	1.7	188	1.7	249	0.5	310	3.3	371	2.5
67	2.3	128	1.9	189	1.2	250	0.9	311	1.3	372	1.2
68	1.2	129	1	190	1.4	251	2.1	312	2.6	373	2.5
69	0.5	130	1.3	191	1.4	252	1.6	313	1.1	374	2.5
70	2.3	131	1.9	192	1.5	253	1.3	314	2.5	375	0.5
71	1.2	132	1.9	193	2.7	254	1.1	315	2.4	376	1.8
72	1.7	133	3.3	194	0.6	255	1.4	316	1.6	377	2.5
73	1.7	134	1	195	1.8	256	1	317	1.2	378	2.6
74	3.1	135	2.4	196	3.2	257	2.1	318	2.4	379	0.7
75	1.3	136	3.3	197	0.7	258	1.8	319	0.7	380	2
76	1.7	137	1.8	198	4.5	259	1.2	320	1.7	381	3.8
77	1.1	138	2.8	199	1.8	260	2.2	321	1	382	1
78	3.1	139	2.1	200	0.8	261	0.4	322	2.6	383	1.7
79	3.2	140	1.9	201	2.4	262	2.8	323	2.2	384	2.1
80	1.8	141	2.6	202	2	263	1.8	324	2.7	385	2.8
81	2	142	0.8	203	1.8	264	3.6	325	0.9		

General Surgery:

Day	Excess	Day	Excess	Day	Excess	Day	Excess	Day	Excess	Day	Excess
21	0.3	82	2.9	143	4.6	204	3.4	265	2	326	1.3
22	2.4	83	1.7	144	1.3	205	6.6	266	3.3	327	3.1
23	3.9	84	5.1	145	5.5	206	1	267	3.1	328	3.4
24	3.5	85	5.2	146	3.6	207	2.5	268	2.7	329	3.1
25	4.8	86	5.9	147	4	208	2.5	269	2.9	330	3.9
26	2.1	87	1.6	148	3.8	209	3	270	5	331	4.4
27	3.7	88	1.6	149	3.1	210	5.3	271	1	332	0.2
28	1	89	1	150	0.8	211	1.7	272	4	333	4.6
29	4.5	90	2.7	151	2.1	212	2.3	273	3.6	334	2.2
30	4.2	91	5.2	152	4.7	213	0.9	274	4.5	335	3
31	3	92	3.7	153	2.8	214	3.8	275	0.8	336	3.4
32	1.1	93	1.5	154	3	215	6.1	276	3.5	337	2.9
33	2.8	94	4.4	155	6	216	3.7	277	6	338	3.4
34	1.5	95	5.3	156	2.3	217	1.4	278	4.5	339	1.6
35	4.9	96	2.2	157	4.5	218	2.4	279	4	340	3.4
36	7.1	97	6.1	158	5	219	0.8	280	1.7	341	3.9
37	1.6	98	2.2	159	3.2	220	6.1	281	1.7	342	1.2
38	2.7	99	5.2	160	4	221	1.8	282	4.9	343	5
39	3.4	100	3.3	161	1.9	222	4.7	283	4.9	344	1.7
40	3.9	101	2.5	162	1.1	223	4.3	284	0.5	345	2.9
41	2.6	102	2	163	1.6	224	2.8	285	1.8	346	2.5
42	6.7	103	4.2	164	4	225	2.3	286	5.8	347	5.4
43	1.9	104	3.2	165	1.3	226	1.2	287	4.6	348	2
44	2.6	105	1.9	166	6.3	227	3.1	288	0.4	349	5.1
45	2.1	106	5	167	3.2	228	2.1	289	3.5	350	4.4
46	5.5	107	2.2	168	0	229	5.8	290	1.7	351	0.3
47	1	108	4.7	169	2.8	230	1.1	291	3.8	352	1.9
48	3.7	109	3.2	170	2.8	231	2.2	292	3.4	353	2.6
49	2.3	110	3.4	171	3.6	232	5	293	1.1	354	4.9
50	4.6	111	1.6	172	0.9	233	2.8	294	3	355	0.2
51	3.8	112	1.2	173	2.8	234	1.9	295	2.7	356	7
52	1	113	4.1	174	7	235	2	296	4.3	357	2.7
53	5.6	114	5.2	175	4.7	236	1.8	297	2.9	358	3.8
54	1.8	115	1.8	176	2.6	237	2.3	298	4.3	359	2.1
55	0.4	116	1.9	177	1.3	238	3.6	299	1.8	360	2.4
56	2.3	117	3.4	178	5.8	239	2.6	300	1.3	361	3
57	5	118	1.8	179	2	240	1.5	301	3.2	362	6.7
58	1.8	119	1.6	180	3.5	241	2.9	302	2.8	363	0.6
59	5.2	120	3.4	181	1.8	242	4.5	303	2.7	364	2.4
60	3.1	121	5.3	182	4.1	243	1.4	304	4.8	365	4.8
61	1.2	122	5.1	183	4.8	244	4.8	305	3.2	366	1.9
62	7.4	123	5.3	184	1.9	245	3	306	1.6	367	4.8
63	3.1	124	3	185	2.8	246	6.6	307	2.7	368	1.3
64	5.2	125	2.5	186	3.5	247	1.5	308	6.2	369	2
65	3.2	126	1.1	187	3.9	248	1.9	309	1.8	370	3.1
66	1.9	127	4.1	188	1.6	249	2.8	310	4.1	371	4.8
67	2.3	128	3.8	189	3.3	250	2.9	311	2.3	372	2.8
68	4.8	129	2.4	190	3.3	251	1.6	312	3.1	373	6.3
69	1.9	130	2	191	1.4	252	6.7	313	5.1	374	4.7
70	3.2	131	4	192	4.4	253	4.8	314	4.1	375	0.6
71	3.3	132	2.6	193	4.9	254	0.3	315	2.3	376	2.7
72	3.6	133	3.9	194	3.6	255	2.7	316	1.1	377	3.4
73	3	134	5.4	195	2.7	256	3.4	317	2.3	378	0.8
74	2.5	135	3.4	196	2.6	257	2.4	318	1.2	379	2.6
75	3.2	136	2.7	197	3.3	258	1.9	319	2.6	380	4.3
76	3	137	5	198	5.6	259	2.9	320	4.2	381	4.1
77	2.1	138	2	199	4.1	260	3.7	321	1.3	382	3.2
78	3.5	139	4	200	1.8	261	4.7	322	5.6	383	3.2
79	1.9	140	3.5	201	2.2	262	2.3	323	4.9	384	3
80	5.9	141	2.1	202	4.9	263	6.2	324	3.7	385	1.8
81	2.9	142	1.2	203	1.7	264	1.8	325	3.8		

ICU:

Day	Excess	Day	Excess	Day	Excess	Day	Excess	Day	Excess	Day	Excess
21	1.2	82	3.7	143	1.8	204	2	265	5.8	326	3.3
22	2.6	83	5.6	144	5	205	6.1	266	5	327	1.7
23	3.9	84	2.1	145	2.4	206	4.7	267	5.3	328	5.5
24	6	85	4.2	146	5	207	1.5	268	2.8	329	4.2
25	2.7	86	2.2	147	5.1	208	4.4	269	2.8	330	4.2
26	2	87	2.6	148	7.3	209	2.9	270	5.2	331	2.9
27	4.8	88	3.9	149	3.4	210	5.1	271	0.5	332	1.1
28	4.6	89	3.4	150	3.9	211	3.5	272	4.2	333	7.1
29	1.5	90	4.6	151	1.3	212	4.1	273	1.9	334	1.8
30	1.7	91	3.2	152	5.7	213	2.7	274	10.6	335	3.8
31	4.1	92	4.6	153	5.9	214	4.1	275	2.6	336	3.1
32	5.7	93	2	154	2.1	215	7.5	276	3.5	337	4.4
33	6.3	94	2	155	3.3	216	1.9	277	5.5	338	4.1
34	2.2	95	3.9	156	1.1	217	4.6	278	4.1	339	4.6
35	1.4	96	3.7	157	0.8	218	7.7	279	2.7	340	4
36	5.8	97	1.2	158	5.5	219	5	280	6.6	341	3.3
37	4.7	98	5.2	159	2.3	220	2.9	281	2.3	342	4.7
38	2.3	99	6.5	160	3.2	221	3.1	282	3.9	343	5.2
39	3.4	100	2.4	161	6.6	222	4.8	283	4.7	344	2.4
40	1.8	101	1.6	162	1.5	223	3.2	284	4	345	2.5
41	4.3	102	3.2	163	4.9	224	5.6	285	2.5	346	4.3
42	2.1	103	4.4	164	2.5	225	1.4	286	4.2	347	6.2
43	5.9	104	2.9	165	3.3	226	2.1	287	3.9	348	1.6
44	4	105	2.4	166	2.7	227	2.6	288	2.1	349	4.2
45	1.1	106	6.3	167	1.2	228	2.2	289	1.8	350	1.2
46	2.7	107	5.2	168	5.9	229	2.4	290	6.2	351	2.9
47	6.6	108	1.4	169	5.2	230	3	291	4.1	352	4.6
48	1.9	109	3.4	170	0.9	231	3.8	292	3.5	353	5.2
49	4.5	110	6.4	171	3.4	232	1.7	293	3.4	354	2.1
50	2.4	111	1.5	172	2.3	233	3.5	294	1.5	355	3.4
51	5.9	112	2.5	173	3.8	234	4.4	295	3.1	356	5.6
52	4.1	113	3.9	174	3.1	235	7.4	296	4.9	357	4.1
53	2.9	114	5.3	175	4.5	236	0.8	297	1.5	358	5.4
54	4.5	115	3.1	176	2.7	237	4.4	298	7.9	359	2.9
55	3.7	116	2.7	177	4.2	238	3.3	299	4.6	360	1.3
56	4.5	117	6	178	4.9	239	2.2	300	2.4	361	2.7
57	2.7	118	3	179	3.8	240	1.5	301	3.8	362	5
58	2.6	119	2.8	180	3.1	241	1.7	302	2.5	363	2.8
59	4.6	120	4.9	181	4	242	7.1	303	0.9	364	3.4
60	4.3	121	2.3	182	1.7	243	5.9	304	4.9	365	5.7
61	2.8	122	5.7	183	4.6	244	0.9	305	5.4	366	4.3
62	3.4	123	0	184	4.5	245	2.6	306	2.1	367	2.2
63	4.5	124	5.3	185	6	246	2	307	2.6	368	3.4
64	1.4	125	3	186	4.4	247	3.2	308	1.7	369	7.8
65	2.4	126	7.8	187	0.5	248	3.6	309	5.6	370	4.5
66	6.2	127	2.3	188	1.8	249	3.9	310	1.5	371	0.8
67	4.8	128	2.8	189	6.8	250	4.7	311	4.1	372	5.4
68	2.1	129	0.7	190	5	251	2.3	312	4.3	373	1.7
69	2.3	130	4.9	191	5.2	252	2.8	313	1.4	374	0.8
70	2.2	131	2.8	192	7.6	253	5.2	314	0.9	375	2.1
71	2.3	132	5.8	193	2	254	6.2	315	9.6	376	5.3
72	3	133	3	194	1.6	255	2.4	316	3.2	377	2.2
73	2.7	134	1.9	195	2.8	256	3.7	317	5.9	378	2.1
74	6.7	135	9.5	196	4	257	7.4	318	2.1	379	1.7
75	6.1	136	3.5	197	2.2	258	5.2	319	5	380	3.7
76	2.6	137	5	198	2.6	259	4.3	320	2.1	381	4.1
77	6.1	138	2.8	199	2.8	260	2.3	321	2	382	3.9
78	2.6	139	5.8	200	1.8	261	6	322	5.8	383	2.2
79	4.6	140	3.1	201	3.5	262	3.7	323	6.5	384	7.3
80	1.9	141	1.9	202	2.3	263	1.8	324	6.2	385	3.8
81	2.3	142	4.1	203	2	264	5.5	325	4.3		

Medical Program:

Day	Excess	Day	Excess	Day	Excess	Day	Excess	Day	Excess	Day	Excess
21	3.4	82	1.9	143	0.7	204	1.4	265	1.1	326	0.9
22	0.2	83	1.1	144	2.7	205	2.1	266	1	327	3
23	1.3	84	3	145	1.7	206	1.8	267	1.6	328	1.7
24	1.3	85	0.5	146	1	207	1.4	268	0.4	329	2.7
25	1.6	86	1.9	147	1.4	208	2	269	1	330	0.8
26	2.6	87	0.9	148	0.6	209	1.3	270	1.3	331	1.3
27	1.4	88	2.4	149	3.6	210	1.7	271	0.8	332	1.1
28	2	89	1	150	0.6	211	1.3	272	1.9	333	1.9
29	1.2	90	1.7	151	0.8	212	2.4	273	1.8	334	1.1
30	3.4	91	1.7	152	3	213	1.4	274	0.6	335	1.6
31	1.3	92	1.1	153	1	214	2.3	275	2.7	336	3.9
32	1.4	93	1.8	154	2.4	215	1.4	276	1.8	337	0.4
33	2.2	94	1.3	155	0.2	216	1.4	277	1.7	338	1.7
34	1.9	95	1.7	156	1.1	217	2.8	278	2.3	339	1.6
35	1.3	96	2.6	157	2.8	218	1.1	279	1.9	340	0.4
36	2.3	97	1.5	158	0.9	219	1.4	280	1.4	341	1.5
37	1.4	98	1	159	1.8	220	2.8	281	0.5	342	1.1
38	1.4	99	2	160	1	221	0.5	282	1.4	343	1.2
39	2.2	100	1.1	161	0.8	222	1.8	283	3.4	344	1.9
40	1.3	101	2	162	1.9	223	2	284	1	345	1.4
41	1.5	102	1.6	163	1.5	224	1.6	285	1.8	346	3
42	1.9	103	1.2	164	2.5	225	0.9	286	1.3	347	1.9
43	0.8	104	1.7	165	0.5	226	2.2	287	2	348	0.7
44	2.8	105	2	166	0.8	227	2	288	2	349	2.8
45	1.2	106	1.3	167	2.4	228	1	289	2.1	350	1
46	0.9	107	0.5	168	1.9	229	0.8	290	1.5	351	2.2
47	2.3	108	1.6	169	1.3	230	2.2	291	1.3	352	0.9
48	0.9	109	0.9	170	1.7	231	1.1	292	1.1	353	1.5
49	1.5	110	2.4	171	2.7	232	1.5	293	1.4	354	2.5
50	2.6	111	0.9	172	2.4	233	3.6	294	2	355	1.7
51	1.2	112	0.9	173	0.7	234	1.8	295	0.3	356	1.9
52	3.1	113	0.6	174	1	235	2.2	296	2.1	357	0.8
53	0.6	114	1.8	175	0.9	236	1.6	297	2.5	358	0.9
54	1.2	115	1	176	1.5	237	1.4	298	1.6	359	1.4
55	1	116	3.1	177	1.4	238	0.4	299	3.4	360	1.6
56	1.8	117	0.7	178	2.2	239	0.6	300	1.5	361	1.3
57	1.4	118	1.6	179	1.8	240	1.5	301	0.7	362	0.8
58	1.6	119	2.3	180	1.8	241	0.9	302	1.5	363	2.1
59	0.9	120	1.8	181	1.4	242	0.6	303	0.7	364	1.7
60	1.7	121	1.8	182	2.3	243	2.4	304	2.1	365	2
61	1.7	122	1.7	183	1.7	244	1.8	305	2	366	1.4
62	1.2	123	1.9	184	2.6	245	0.4	306	0.5	367	1.1
63	3.4	124	1.9	185	0	246	2.5	307	3	368	1.6
64	0.4	125	2.8	186	2.2	247	3	308	1.9	369	2.3
65	1.4	126	2	187	1.4	248	0.4	309	0.6	370	0.9
66	2.6	127	1.2	188	0.6	249	1.7	310	2.2	371	2.1
67	0.9	128	1	189	2	250	0.8	311	1.4	372	1.2
68	0.5	129	0.2	190	0.7	251	2	312	2.7	373	1.1
69	1.9	130	2.2	191	0.9	252	1.6	313	1	374	2.1
70	1.7	131	3.1	192	1.7	253	1.1	314	1.7	375	2.2
71	1.3	132	2.2	193	2.3	254	4.1	315	0.2	376	1.2
72	1	133	2.7	194	1.4	255	0.7	316	1.8	377	1.1
73	1.5	134	0.7	195	3	256	2.4	317	0.1	378	1.6
74	1.9	135	2.2	196	1.3	257	1.1	318	1.5	379	1.4
75	1.6	136	1	197	2.5	258	1.7	319	2.9	380	1.2
76	0.5	137	1.8	198	0.5	259	1.6	320	1	381	1
77	2.1	138	1.9	199	1.6	260	1.7	321	2.7	382	0.9
78	2.4	139	0.6	200	1.5	261	2.2	322	0.9	383	2.3
79	1.3	140	3	201	0.9	262	0.7	323	2.2	384	1.1
80	1.3	141	1.3	202	1	263	2.5	324	1.2	385	2.2
81	0.5	142	2.4	203	1.5	264	1.7	325	2.6		

Oncology:

Day	Excess	Day	Excess	Day	Excess	Day	Excess	Day	Excess	Day	Excess
21	0.4	82	0.6	143	1.8	204	0.9	265	1.3	326	0.8
22	1.8	83	1.2	144	0.3	205	0.6	266	0.6	327	2
23	1.9	84	0.5	145	1.9	206	1.4	267	0.6	328	0.5
24	1.8	85	1.7	146	1.1	207	1.4	268	2	329	1.7
25	0.3	86	1.2	147	1.4	208	1.1	269	0.5	330	2.4
26	2	87	0.3	148	0.5	209	0.7	270	1.6	331	0.7
27	1.5	88	1.4	149	0.5	210	0.2	271	1.4	332	0.6
28	0.5	89	0.6	150	1.2	211	1.4	272	1.4	333	0.5
29	1.5	90	1.5	151	0.8	212	0.2	273	3.2	334	0.3
30	1.2	91	0.2	152	0.2	213	1.4	274	0.2	335	2
31	0.6	92	1.3	153	1.9	214	1.2	275	0.6	336	1.1
32	2.2	93	1.4	154	1.4	215	0.2	276	1.5	337	0.4
33	0.8	94	1.3	155	0.6	216	1.6	277	1.1	338	1.4
34	1.2	95	0.9	156	0.7	217	1.3	278	1.7	339	0.7
35	0.7	96	0.4	157	3	218	2.2	279	0.9	340	2.4
36	1.9	97	0.4	158	1	219	1.2	280	1.2	341	1.4
37	1.4	98	0.8	159	0.9	220	1.7	281	0.7	342	1.3
38	1.8	99	2.6	160	1	221	0.7	282	1	343	1
39	1.4	100	1.6	161	0.9	222	2.3	283	1.1	344	1
40	0.6	101	0.4	162	1.2	223	1.4	284	1.6	345	0.9
41	1.6	102	1.3	163	1.4	224	0	285	1.1	346	1
42	0.8	103	1.7	164	0.6	225	2.8	286	1.2	347	1.2
43	0.7	104	1	165	1.8	226	1.1	287	2.1	348	1.5
44	1.9	105	0.9	166	0.9	227	1.5	288	1.1	349	1.1
45	1.2	106	1.1	167	1.6	228	0.7	289	1	350	0.9
46	0.9	107	1	168	1.2	229	2	290	0.7	351	0.8
47	1.2	108	0.6	169	0.8	230	0.8	291	2.1	352	0.1
48	1.1	109	1.4	170	1.6	231	0.5	292	0.9	353	1.2
49	2	110	1.1	171	1.7	232	0.5	293	1.3	354	1.5
50	0.9	111	1.2	172	1.3	233	1.2	294	0.9	355	1.2
51	0.6	112	1	173	1.2	234	0.8	295	2.1	356	0.7
52	1.4	113	1.9	174	1.2	235	1.2	296	0.5	357	1.1
53	0.6	114	0.9	175	1.2	236	1.1	297	1.1	358	1.3
54	1.2	115	0.2	176	0.2	237	0.9	298	1.6	359	1
55	2	116	1.8	177	1.6	238	1.1	299	0.5	360	0.1
56	1.1	117	1	178	1.5	239	1.5	300	1.3	361	0.5
57	1.1	118	1.1	179	0.4	240	2	301	1.8	362	0.9
58	0.6	119	1.2	180	0.6	241	0.6	302	1.9	363	0.9
59	0.3	120	0.9	181	1.1	242	0.7	303	1	364	1.8
60	0.5	121	1.3	182	2.6	243	1	304	1	365	2
61	0.8	122	2.8	183	0.6	244	1.1	305	0.6	366	2.8
62	1.2	123	0.2	184	0.9	245	0.9	306	0.4	367	1
63	0.5	124	1.1	185	0.4	246	0.6	307	1.3	368	0.2
64	2.7	125	1.2	186	1.4	247	1.4	308	1.6	369	2.2
65	0.8	126	0.9	187	1	248	1.1	309	2.5	370	1.2
66	1.8	127	0.8	188	0.8	249	0.5	310	1.6	371	0.5
67	1.1	128	1.8	189	0.8	250	2.1	311	0.8	372	1.5
68	0.7	129	1	190	0.1	251	0.4	312	1.3	373	1.3
69	1.5	130	1.5	191	1.9	252	0.4	313	0.5	374	1.3
70	1	131	1	192	1.8	253	0.5	314	0.9	375	0.4
71	1.4	132	1.8	193	0.7	254	1.4	315	0.8	376	1.6
72	1.2	133	1.4	194	1.3	255	1.1	316	0.7	377	0.9
73	0.6	134	1.6	195	1.2	256	0.9	317	2	378	0.9
74	1.5	135	1.2	196	0.7	257	0.5	318	0.9	379	1.4
75	2.1	136	1.9	197	0.9	258	1.1	319	0.9	380	2
76	1.4	137	0.8	198	0.7	259	0.9	320	0.7	381	1.1
77	1.6	138	0.5	199	1.5	260	1.7	321	1	382	0.7
78	0.4	139	0.8	200	1.4	261	1	322	0.4	383	1.7
79	1.8	140	1.5	201	0.6	262	1.8	323	4	384	1.4
80	1.2	141	1.4	202	2	263	1.2	324	0.6	385	1.2
81	1.4	142	0.6	203	1.4	264	0.8	325	1.6		

Paediatrics:

Day	Excess	Day	Excess	Day	Excess	Day	Excess	Day	Excess	Day	Excess
21	1.8	82	3.3	143	1.8	204	1.3	265	2.8	326	2
22	2.5	83	0.9	144	0.3	205	1.2	266	2.1	327	0.8
23	2.1	84	1.6	145	2	206	1	267	1.3	328	2.3
24	0.9	85	1.8	146	1.6	207	0.9	268	1.3	329	2.1
25	1.6	86	2	147	2.5	208	1.1	269	1.1	330	0.5
26	1.6	87	0.9	148	2.7	209	1.3	270	2.8	331	3.1
27	1.8	88	1.1	149	1.2	210	1	271	1.6	332	1.2
28	2	89	1.5	150	2.7	211	2.4	272	1.6	333	2.3
29	1.6	90	2.1	151	1.8	212	1.7	273	2.5	334	0.2
30	2.4	91	2.7	152	1.6	213	1.9	274	1.5	335	3.3
31	0.9	92	1	153	0.7	214	1.3	275	1.6	336	1.7
32	1.3	93	1.1	154	3.1	215	1.7	276	1.1	337	1.7
33	1.8	94	1.5	155	2.3	216	2	277	0	338	1.6
34	1.2	95	0.9	156	1.5	217	0.2	278	1.9	339	1.1
35	2.9	96	3.9	157	2.1	218	3.4	279	3	340	1.1
36	1	97	2.2	158	0.8	219	1.5	280	0.9	341	2.2
37	2.1	98	3.5	159	1	220	1.5	281	1.5	342	1.1
38	2.2	99	0.9	160	0.7	221	1.6	282	2.5	343	1.6
39	3.6	100	1.1	161	1	222	0.4	283	2	344	2.6
40	0.8	101	1.6	162	1	223	1.5	284	1.5	345	1.5
41	0.3	102	1.5	163	3	224	2.4	285	1.6	346	1.7
42	1.9	103	0.8	164	2.2	225	2.3	286	1.1	347	0.8
43	2.4	104	2.4	165	2.6	226	1.1	287	1	348	0.4
44	1.8	105	2.2	166	0.1	227	0.7	288	1.3	349	2.2
45	1.3	106	0.4	167	2.8	228	2.4	289	0.7	350	1.4
46	1.9	107	1.3	168	1.3	229	1.7	290	2.8	351	3.1
47	1.1	108	0.6	169	1.8	230	1.2	291	2.3	352	1.3
48	1.5	109	2.4	170	2.3	231	1.2	292	2.1	353	2.1
49	1.6	110	3.2	171	1.1	232	2.4	293	1.9	354	1.6
50	2.4	111	0.6	172	1	233	1.7	294	2.5	355	2.1
51	1	112	2.6	173	3.7	234	2.3	295	2.3	356	2.7
52	0.7	113	2	174	1.4	235	0.4	296	0.4	357	2.5
53	2.5	114	2.8	175	2	236	3.4	297	1.5	358	0.8
54	0.9	115	0.7	176	0.8	237	1.6	298	1.4	359	1.6
55	2.5	116	2	177	2	238	0.7	299	3.1	360	1.4
56	2.7	117	2.2	178	2.4	239	2.5	300	1.5	361	2.5
57	2.4	118	1.6	179	2.2	240	1.4	301	1.3	362	1.4
58	1.9	119	1.3	180	1.8	241	1.1	302	1.8	363	1
59	0.8	120	0.5	181	0.6	242	1.2	303	0.3	364	2.9
60	2.6	121	3.1	182	3.1	243	1.3	304	2.7	365	0.5
61	2.4	122	0.6	183	1.3	244	2.4	305	0.3	366	2.4
62	1.3	123	0.6	184	1.5	245	1.1	306	1.2	367	2.7
63	2.5	124	1.5	185	1.2	246	0.5	307	3.4	368	0.2
64	0.8	125	1.4	186	3.9	247	1.9	308	0.7	369	1.5
65	0.9	126	1.1	187	0.8	248	0.6	309	2.5	370	2.8
66	1.6	127	2.9	188	1.3	249	3.1	310	0.8	371	1.5
67	3.3	128	1.2	189	2.5	250	2.4	311	0.6	372	1.8
68	1	129	1.6	190	1.9	251	2.9	312	1.6	373	1.3
69	1.9	130	2.1	191	1.1	252	1.1	313	0.8	374	1.1
70	2.3	131	0.8	192	0.7	253	2	314	1.3	375	3.1
71	3.8	132	3.2	193	2.5	254	0.6	315	2.4	376	3.4
72	1.6	133	2.6	194	2	255	0.6	316	1.4	377	2.3
73	1.1	134	1.9	195	2.2	256	3.9	317	1.5	378	2.5
74	0.7	135	1.4	196	2.1	257	0.3	318	0.7	379	0.4
75	1.2	136	1.3	197	1.1	258	3.8	319	2.4	380	2.2
76	1.7	137	1	198	1.6	259	0.5	320	0.5	381	2.1
77	1.3	138	1.7	199	1.1	260	2.3	321	2.9	382	2.5
78	3.1	139	1.4	200	3	261	1.2	322	1.6	383	2
79	2.5	140	0.3	201	2.4	262	1.5	323	1.4	384	1.4
80	1.1	141	2.1	202	0.6	263	1.9	324	2.4	385	1.5
81	1	142	3	203	2.6	264	0.5	325	1.4		

Appendix H

Average Time (in Hours) Spent to Retrieve Pumps per Day, by Department – Current System

CCU:

Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours
21	0.06	82	0.42	143	0.57	204	0.54	265	1.02	326	0.6
22	0.39	83	0.51	144	0.15	205	0.18	266	0.69	327	0.42
23	0.93	84	0.81	145	0.45	206	0.57	267	0.75	328	0.36
24	0.39	85	0.36	146	0.6	207	0.24	268	0.72	329	0.69
25	0.87	86	0.72	147	0.66	208	0.51	269	0.75	330	0.06
26	0.45	87	0.36	148	0.69	209	0.39	270	0.39	331	1.11
27	0.6	88	1.02	149	0.66	210	0.57	271	0.51	332	0.51
28	0.81	89	0.6	150	0.15	211	0.51	272	0.42	333	0.66
29	0.27	90	0.6	151	1.08	212	0.51	273	0.63	334	0.12
30	0.6	91	0.33	152	0.39	213	0.78	274	0.24	335	0.81
31	0.3	92	0.48	153	0.69	214	0.81	275	1.14	336	0.6
32	0.39	93	0.54	154	0.45	215	0.27	276	0.27	337	0.72
33	0.27	94	0.42	155	0.24	216	0.45	277	1.08	338	0.3
34	0.24	95	0.66	156	0.18	217	0.3	278	0.3	339	0.54
35	1.02	96	0.66	157	0.72	218	0.75	279	0.69	340	0.6
36	0.63	97	0.66	158	0.48	219	0.36	280	0.33	341	0.66
37	0.27	98	0.12	159	0.09	220	0.51	281	0.33	342	0.36
38	0.93	99	0.27	160	0.57	221	0.54	282	0.51	343	0.63
39	0.48	100	0.48	161	1.26	222	1.26	283	0.33	344	0.21
40	0.81	101	0.72	162	0.27	223	0.72	284	0.51	345	0.42
41	1.2	102	0.24	163	0.21	224	0.75	285	0.27	346	0.75
42	0.42	103	0.66	164	0.33	225	0.33	286	0.6	347	0.27
43	0.66	104	0.15	165	0.57	226	0.51	287	1.08	348	0.63
44	0.57	105	0.87	166	0.78	227	0.36	288	0.06	349	0.57
45	0.39	106	0.63	167	0.39	228	0.24	289	0.24	350	0.39
46	0.09	107	0.96	168	0.33	229	0.63	290	0.72	351	0.72
47	1.44	108	1.11	169	0.51	230	0.48	291	0.42	352	0.69
48	0.12	109	0.69	170	0.36	231	0.78	292	0.6	353	0.15
49	0.66	110	0.15	171	0.33	232	0.12	293	0.72	354	0.96
50	0.69	111	0.42	172	0.84	233	0.69	294	0.54	355	0.42
51	0.3	112	0.21	173	0.42	234	0.39	295	0.33	356	0.54
52	0.24	113	0.75	174	0.27	235	0.87	296	0.27	357	0.36
53	0.72	114	0.42	175	0.33	236	0.3	297	0.33	358	0.48
54	0.78	115	0.81	176	0.57	237	0.81	298	0.84	359	0.33
55	1.35	116	0.87	177	0.48	238	0.51	299	0.75	360	0.54
56	0.39	117	0.33	178	1.14	239	0.3	300	0.51	361	0.42
57	0.24	118	0.72	179	0.75	240	0.6	301	0.72	362	0.6
58	0.36	119	0.39	180	0.18	241	1.29	302	0.36	363	0.36
59	0.66	120	0.51	181	0.63	242	0.42	303	0.93	364	0.24
60	0.33	121	0.63	182	0.6	243	0.15	304	0.48	365	0.75
61	1.17	122	0.69	183	0.96	244	0.6	305	0.27	366	0.51
62	0.33	123	0.36	184	0.57	245	0.39	306	0.24	367	0.57
63	0.3	124	0.18	185	0.66	246	0.36	307	0.48	368	0.48
64	0.57	125	0.45	186	0.6	247	0.45	308	0.78	369	1.05
65	0.3	126	0.6	187	0.84	248	0.15	309	0.24	370	0.93
66	0.96	127	0.6	188	0.9	249	1.29	310	0.81	371	0.3
67	0.3	128	0.6	189	0.69	250	0.21	311	0.66	372	0.96
68	0.84	129	0.87	190	0.21	251	0.09	312	0.9	373	0.3
69	0.42	130	0.78	191	0.51	252	0.45	313	0.6	374	0.72
70	0.6	131	0.24	192	0.45	253	0.21	314	0.51	375	1.02
71	0.27	132	0.51	193	0.45	254	0.72	315	0.45	376	0.42
72	0.42	133	0.12	194	0.72	255	0.48	316	0.84	377	0.63
73	0.87	134	1.05	195	0.57	256	0.42	317	0.39	378	0.48
74	0.42	135	0.63	196	0.24	257	0.15	318	0.18	379	0.63
75	1.17	136	0.75	197	0.6	258	0.42	319	0.51	380	0.63
76	0.27	137	0.9	198	0.6	259	0.72	320	0.51	381	0.24
77	0.3	138	0.21	199	0.72	260	0.45	321	0.75	382	0.87
78	0.39	139	0.69	200	0.63	261	0.78	322	0.36	383	0.18
79	0.3	140	0.27	201	0.57	262	0.48	323	0.45	384	0.3
80	0.93	141	0.72	202	0.57	263	0.45	324	0.33	385	0.15
81	0.63	142	1.14	203	0.66	264	0.54	325	1.05		

General Surgery:

Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours
21	1.68	82	0.78	143	0.78	204	0.48	265	1.17	326	2.07
22	1.2	83	1.35	144	0.75	205	0.69	266	1.56	327	0.69
23	0.18	84	0.12	145	1.17	206	0.84	267	1.11	328	0.57
24	1.74	85	0.54	146	0.99	207	0.81	268	1.23	329	1.56
25	1.08	86	0.54	147	0.57	208	2.16	269	1.05	330	0.51
26	1.08	87	2.43	148	0.66	209	0.45	270	0.15	331	0.45
27	0.36	88	0.63	149	0.81	210	0.75	271	0.81	332	2.16
28	0.66	89	1.8	150	1.02	211	1.14	272	1.14	333	0.84
29	0.72	90	1.41	151	1.8	212	0.51	273	1.2	334	1.11
30	1.32	91	1.08	152	0.66	213	1.02	274	0.51	335	0.45
31	0.93	92	1.02	153	1.29	214	0.66	275	1.35	336	0.66
32	1.35	93	0.81	154	0.99	215	0.21	276	0.33	337	0.6
33	1.08	94	0.54	155	0.63	216	0.75	277	0.87	338	0.75
34	1.02	95	0.45	156	0.96	217	1.53	278	0.96	339	1.32
35	0.42	96	2.16	157	1.56	218	1.41	279	1.02	340	0.48
36	0.87	97	0.51	158	0.9	219	1.8	280	1.62	341	0.9
37	1.59	98	1.98	159	1.05	220	0.48	281	0.93	342	1.14
38	0.9	99	0.84	160	0.81	221	1.17	282	0.63	343	0.63
39	0.78	100	0.78	161	0.63	222	0.69	283	0.51	344	1.08
40	0.66	101	0.54	162	0.87	223	1.08	284	2.43	345	1.11
41	1.41	102	1.53	163	1.2	224	1.02	285	1.5	346	1.2
42	0.69	103	0.87	164	0.84	225	0.6	286	0.21	347	0.66
43	1.14	104	0.93	165	1.2	226	0.99	287	1.05	348	0.84
44	1.86	105	1.17	166	0.06	227	1.11	288	1.53	349	0.9
45	1.14	106	0.81	167	0.51	228	0.57	289	0.18	350	0.42
46	0.63	107	1.2	168	1.95	229	0.12	290	0.3	351	1.41
47	1.68	108	0.78	169	0.75	230	1.95	291	1.08	352	0.84
48	0.54	109	0.69	170	1.05	231	0.48	292	0.63	353	0.27
49	0.63	110	0.09	171	0.84	232	0.33	293	1.26	354	1.02
50	0.45	111	0.96	172	1.29	233	0.96	294	1.44	355	1.86
51	0.54	112	1.05	173	0.87	234	0.63	295	0.63	356	0.24
52	1.62	113	0.99	174	0.63	235	1.17	296	0.3	357	0.51
53	0.18	114	0.69	175	0.63	236	0.57	297	0.54	358	0.63
54	1.77	115	1.38	176	0.57	237	0.57	298	0.69	359	0.87
55	1.74	116	0.99	177	1.59	238	0.9	299	1.29	360	0.6
56	0.87	117	1.32	178	0.87	239	1.23	300	0.75	361	1.68
57	0	118	1.02	179	0.57	240	1.62	301	0.36	362	1.38
58	2.01	119	1.53	180	1.65	241	0.9	302	1.68	363	1.59
59	1.23	120	0.48	181	1.11	242	0.84	303	0.81	364	1.11
60	0.72	121	0.42	182	1.23	243	0.87	304	0.66	365	0.42
61	1.29	122	1.17	183	0.9	244	0.72	305	1.05	366	1.62
62	0.78	123	1.5	184	2.1	245	1.32	306	1.53	367	1.02
63	1.47	124	1.17	185	0.72	246	0.15	307	1.41	368	1.2
64	0.45	125	0.51	186	0.27	247	1.44	308	0.27	369	1.11
65	1.5	126	1.77	187	0.42	248	1.44	309	1.02	370	1.02
66	1.11	127	0.66	188	1.23	249	0.57	310	0.36	371	0.66
67	0.75	128	1.08	189	1.2	250	0.96	311	0.93	372	1.14
68	0.24	129	0.78	190	0.87	251	0.75	312	1.2	373	0.54
69	1.41	130	1.29	191	0.66	252	1.05	313	1.14	374	0.66
70	0.72	131	0.6	192	0.9	253	0.93	314	0.6	375	1.74
71	1.14	132	1.05	193	0.9	254	1.98	315	0.69	376	0.57
72	0.45	133	1.68	194	0.57	255	0.39	316	1.05	377	1.83
73	1.35	134	0.69	195	1.26	256	1.05	317	0.84	378	0.78
74	1.38	135	0.42	196	0.81	257	0.54	318	1.44	379	0.84
75	0.6	136	1.44	197	1.29	258	1.26	319	0.57	380	0.66
76	0.42	137	0.12	198	1.02	259	1.02	320	0.51	381	0.48
77	0.96	138	1.14	199	0.81	260	0.51	321	1.32	382	0.96
78	0.69	139	0.6	200	0.96	261	0.36	322	0.99	383	0.48
79	1.32	140	1.14	201	1.83	262	1.23	323	1.26	384	0.36
80	0.33	141	1.35	202	0.54	263	0	324	1.17	385	1.47
81	1.14	142	1.65	203	1.23	264	0.78	325	0.6		

ICU:

Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours
21	0.93	82	0.54	143	0.78	204	0.96	265	0.81	326	1.05
22	1.68	83	0.3	144	0.54	205	0.78	266	1.35	327	1.11
23	1.38	84	1.89	145	2.25	206	1.11	267	1.08	328	0.63
24	0.87	85	0.45	146	1.2	207	2.22	268	1.47	329	0.9
25	0.96	86	1.77	147	0.57	208	0.84	269	0.63	330	0.78
26	1.35	87	1.05	148	1.02	209	1.32	270	0.84	331	2.19
27	0.39	88	0.72	149	1.53	210	0.96	271	1.71	332	2.31
28	1.65	89	0.93	150	0.6	211	2.01	272	1.41	333	0.72
29	0.9	90	1.23	151	1.29	212	0.78	273	1.86	334	1.23
30	1.74	91	1.11	152	1.02	213	1.53	274	0.39	335	0.57
31	0.84	92	0.78	153	0.99	214	1.44	275	1.38	336	1.83
32	0.51	93	1.41	154	0.66	215	0.48	276	2.13	337	1.05
33	0.33	94	1.35	155	0.42	216	1.38	277	1.02	338	2.31
34	2.34	95	0.93	156	2.28	217	0.93	278	0.99	339	1.17
35	1.59	96	0.99	157	0.36	218	0.3	279	0.99	340	1.02
36	1.41	97	1.26	158	0.45	219	1.89	280	1.2	341	1.14
37	0.63	98	0.75	159	0.96	220	0.96	281	0.63	342	1.47
38	1.08	99	0.48	160	1.02	221	1.26	282	1.29	343	1.14
39	1.59	100	0.72	161	0.45	222	1.35	283	1.35	344	0.93
40	1.74	101	0.69	162	1.53	223	1.29	284	1.29	345	0.51
41	0.96	102	1.08	163	0.75	224	0.75	285	0.39	346	0.93
42	0.93	103	1.26	164	1.23	225	1.08	286	0.6	347	0.84
43	0.63	104	0.6	165	1.05	226	0.36	287	1.44	348	0.72
44	0.81	105	0.72	166	1.2	227	0.54	288	0.6	349	0.33
45	1.35	106	1.26	167	1.02	228	1.23	289	1.32	350	1.89
46	1.86	107	0.87	168	0.45	229	1.2	290	0.57	351	1.44
47	0.78	108	2.22	169	0.39	230	0.63	291	2.1	352	0.87
48	1.47	109	1.41	170	1.23	231	1.5	292	0.48	353	0.75
49	1.02	110	0.48	171	1.44	232	0.84	293	1.05	354	1.65
50	0.63	111	1.23	172	2.04	233	1.44	294	0.57	355	0.9
51	0.39	112	1.29	173	0.51	234	0.63	295	1.05	356	1.32
52	0.99	113	0.45	174	0.9	235	0.54	296	0.36	357	1.08
53	1.59	114	0.78	175	0.96	236	0.75	297	1.62	358	0.18
54	0.84	115	2.25	176	1.32	237	0.48	298	2.25	359	1.77
55	1.83	116	1.83	177	0.42	238	0.9	299	0.87	360	1.68
56	0.84	117	0.75	178	0.84	239	1.47	300	1.41	361	0.21
57	1.11	118	1.17	179	1.29	240	2.85	301	1.17	362	1.35
58	0.51	119	0.93	180	1.17	241	1.02	302	1.08	363	1.14
59	0.75	120	0.84	181	0.99	242	0.81	303	1.83	364	0.93
60	0.6	121	0.75	182	2.25	243	0.69	304	0.87	365	0.99
61	1.65	122	0.6	183	0.9	244	1.38	305	0.9	366	1.05
62	1.68	123	2.37	184	1.59	245	1.35	306	0.87	367	2.16
63	0.48	124	0.6	185	0.72	246	1.59	307	0.33	368	0.87
64	1.32	125	1.77	186	0.45	247	1.08	308	0.45	369	0.33
65	0.99	126	0.66	187	1.5	248	2.1	309	0.54	370	0.18
66	0.93	127	1.02	188	1.74	249	0.96	310	2.16	371	1.08
67	0.96	128	1.2	189	1.59	250	0.09	311	0.36	372	0.81
68	1.44	129	1.2	190	1.86	251	1.71	312	0.51	373	2.43
69	0.9	130	1.02	191	1.11	252	1.65	313	1.41	374	1.26
70	1.08	131	1.44	192	0.15	253	1.23	314	3	375	1.02
71	0.84	132	1.53	193	0.75	254	0.78	315	0.33	376	0.39
72	1.38	133	1.56	194	1.35	255	1.35	316	2.4	377	1.77
73	1.05	134	1.59	195	0.66	256	1.98	317	0.12	378	1.17
74	0.9	135	0.78	196	1.41	257	0.69	318	1.65	379	1.53
75	1.2	136	0.99	197	1.17	258	1.17	319	0.78	380	1.59
76	1.11	137	0.27	198	1.53	259	0.42	320	0.81	381	0.48
77	0.18	138	1.56	199	0.87	260	1.71	321	1.86	382	1.47
78	1.53	139	0.87	200	0.42	261	0.39	322	1.38	383	0.75
79	0.39	140	1.77	201	0.9	262	1.14	323	0.78	384	0.69
80	1.71	141	1.5	202	1.02	263	2.31	324	0.39	385	0.78
81	1.89	142	1.98	203	1.02	264	0.93	325	0.63		

Medical Program:

Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours
21	0	82	0.27	143	0.96	204	0.18	265	0.33	326	0.87
22	0.69	83	0.57	144	0.06	205	0.51	266	0.51	327	0.18
23	0.45	84	0.48	145	0.36	206	0.78	267	0.33	328	0.39
24	0.24	85	0.84	146	0.69	207	0.51	268	0.18	329	0.21
25	0.75	86	0.33	147	0.45	208	0.18	269	0.72	330	0.6
26	0.42	87	0.36	148	0.45	209	0.6	270	0	331	0.54
27	0.39	88	0.3	149	0.27	210	0.36	271	0.69	332	0.39
28	0.3	89	0.57	150	0.81	211	0.63	272	0.33	333	0.33
29	0.75	90	0.3	151	0.78	212	0.63	273	0.15	334	0.69
30	0.51	91	0.27	152	0.3	213	0.63	274	0.93	335	0.27
31	1.08	92	0.66	153	0.57	214	0.24	275	0.3	336	0.09
32	0.39	93	0.63	154	0.27	215	0.72	276	0.42	337	0.66
33	0.33	94	0.27	155	0.75	216	0.54	277	0.81	338	0.21
34	0.33	95	0.24	156	0.18	217	0.54	278	0.36	339	0.27
35	0.57	96	0.27	157	0.09	218	0.66	279	0.33	340	1.02
36	0.36	97	0.66	158	0.57	219	0.54	280	0.39	341	0.57
37	0.48	98	0.72	159	0.48	220	0.18	281	0.6	342	0.72
38	0.33	99	0.39	160	0.6	221	0.48	282	0.75	343	0.06
39	0.45	100	0.9	161	0.54	222	0.6	283	0.36	344	0.27
40	0.69	101	0.18	162	0.36	223	0.45	284	0.6	345	0.72
41	0.42	102	0.24	163	0.39	224	0.3	285	0.24	346	0.42
42	0.42	103	0.66	164	0.42	225	0.63	286	0.39	347	0.45
43	0.87	104	0.45	165	0.42	226	0.3	287	0.48	348	0.6
44	0.48	105	0.3	166	0.24	227	0.24	288	0.48	349	0.15
45	0.48	106	0.66	167	0.24	228	0.78	289	0.51	350	0.54
46	0.3	107	0.54	168	0.36	229	0.33	290	0.66	351	0.45
47	0.36	108	0.12	169	1.26	230	0.33	291	0.24	352	0.51
48	0.36	109	0.66	170	0.42	231	0.3	292	0.48	353	0.33
49	0.48	110	0.15	171	0.33	232	0.78	293	0.78	354	0.78
50	0.45	111	0.69	172	0.54	233	0.33	294	0.48	355	0.72
51	0.57	112	0.42	173	0.69	234	0.54	295	0.51	356	0.3
52	0.42	113	0.33	174	0.42	235	0.45	296	0.33	357	0.87
53	0.66	114	0.54	175	0.57	236	0.78	297	0.45	358	0.57
54	0.57	115	0.42	176	0.18	237	0.48	298	1.35	359	0.09
55	0.33	116	0.42	177	0.33	238	0.57	299	0.6	360	0.45
56	0.6	117	0.72	178	0.12	239	0.24	300	0.51	361	0.48
57	0.63	118	0.54	179	0.66	240	0.21	301	0.36	362	0.33
58	0.48	119	0.78	180	0.36	241	0.39	302	0.27	363	0.36
59	0.45	120	0.27	181	1.02	242	0.96	303	0.39	364	0.39
60	0.42	121	0.48	182	0.45	243	0.06	304	0.15	365	0.18
61	0.24	122	0.66	183	0.42	244	0.36	305	0.57	366	0.33
62	0.63	123	0.48	184	0.21	245	0.84	306	0.9	367	0.99
63	0.03	124	0.69	185	1.08	246	0.48	307	0.09	368	0.72
64	0.93	125	0.12	186	0.36	247	0.45	308	0.39	369	0.24
65	0.36	126	0.57	187	0.63	248	0.84	309	0.57	370	0.63
66	0.12	127	0.54	188	0.75	249	0.33	310	0.3	371	0.24
67	0.69	128	0.48	189	0.15	250	0.99	311	0.6	372	0.42
68	0.51	129	0.87	190	0.42	251	0.15	312	0.15	373	0.27
69	0.45	130	0.45	191	0.36	252	0.15	313	0.72	374	0.3
70	0.33	131	0.18	192	0.27	253	0.75	314	0.42	375	0.51
71	0.33	132	0.39	193	0.3	254	0.18	315	0.39	376	0.54
72	0.81	133	0.84	194	0.78	255	0.87	316	0.15	377	0.36
73	0.12	134	0.6	195	0.42	256	0.78	317	0.54	378	0.63
74	0.66	135	0.33	196	0.75	257	0.33	318	0.51	379	0.45
75	0.57	136	0.3	197	0.12	258	0.36	319	0.33	380	0.21
76	0.36	137	0.27	198	0.45	259	0.48	320	1.32	381	0.21
77	0.45	138	0.66	199	0.39	260	0.54	321	0.33	382	0.84
78	0.18	139	0.87	200	0.45	261	0.12	322	0.93	383	0.09
79	0.6	140	0.06	201	0.54	262	0.54	323	0.99	384	0.6
80	0.33	141	0.87	202	0.63	263	0.54	324	0.87	385	0.21
81	0.48	142	0.87	203	0.24	264	0.54	325	0.15		

Oncology:

Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours
21	0.81	82	0.3	143	0.39	204	0.69	265	0.3	326	0.45
22	0.21	83	0.57	144	0.51	205	0.27	266	0.39	327	0.06
23	0.45	84	0.51	145	0	206	0.48	267	0.33	328	0.39
24	0.45	85	0.33	146	0.24	207	0.15	268	0.18	329	0.3
25	0.75	86	0.27	147	0.21	208	0.57	269	0.6	330	0.24
26	0.09	87	0.42	148	0.15	209	0.48	270	0.75	331	0.21
27	0.63	88	0.3	149	0.69	210	0.33	271	0.51	332	0.39
28	0.51	89	0.12	150	0.18	211	0.15	272	0.36	333	0.42
29	0.45	90	0.12	151	0.3	212	0.42	273	0.33	334	0.36
30	0.18	91	0.69	152	0.69	213	0.18	274	0.51	335	0.33
31	0.24	92	0.18	153	0.15	214	0.3	275	0.42	336	0.45
32	0.39	93	0.15	154	0.24	215	0.36	276	0.15	337	0.48
33	0.84	94	0.21	155	0.3	216	0.33	277	0.6	338	0.18
34	0.57	95	0.21	156	0.27	217	0.57	278	0.33	339	0.39
35	0.06	96	0.51	157	0.09	218	0	279	0.33	340	0.12
36	0.18	97	0.45	158	0.42	219	0.51	280	0.21	341	0.69
37	0.09	98	0.33	159	0.48	220	0.33	281	0.18	342	0.15
38	0.12	99	0.21	160	0.18	221	0.27	282	0.09	343	0.42
39	0.87	100	0.33	161	0.21	222	0.24	283	0.72	344	0.12
40	0.3	101	0.66	162	0.36	223	0.72	284	0.33	345	0.39
41	0.3	102	0.33	163	0.15	224	0.69	285	0.42	346	0.21
42	0.3	103	0.15	164	0.66	225	0.21	286	0.48	347	0.21
43	0.48	104	0.39	165	0.42	226	0.45	287	0.27	348	0.36
44	0.54	105	0.54	166	0.6	227	0.12	288	0.42	349	0.54
45	0.42	106	0.33	167	0.36	228	0.27	289	0.3	350	0.42
46	0.78	107	0.24	168	0.3	229	0.33	290	0.39	351	0.27
47	0.33	108	0.57	169	0.15	230	0.54	291	0.21	352	0.48
48	0.42	109	0.12	170	0.3	231	0.66	292	0.33	353	0.09
49	0.33	110	0.33	171	0.48	232	0.3	293	0.15	354	0.3
50	0.24	111	0.12	172	0.45	233	0.18	294	0.75	355	0.27
51	0.48	112	0.33	173	0.33	234	0.48	295	0.21	356	0.39
52	0.18	113	0.21	174	0.36	235	0.18	296	0.75	357	0.24
53	0.18	114	0.18	175	0.54	236	0.84	297	0.24	358	0.33
54	0.42	115	0.75	176	0.57	237	0.27	298	0.12	359	0.48
55	0.57	116	0.3	177	0.06	238	0.12	299	0.36	360	0.33
56	0.45	117	0.27	178	0.24	239	0.15	300	0.33	361	0.51
57	0.12	118	0.06	179	0.24	240	0.15	301	0.27	362	0.27
58	0.24	119	0.39	180	0.45	241	0.57	302	0.15	363	0.18
59	0.54	120	0.33	181	0.3	242	0.12	303	0.33	364	0.51
60	0.27	121	0.33	182	0.03	243	0.09	304	0.39	365	0.39
61	0.33	122	0.48	183	0.57	244	0.15	305	0.6	366	0.12
62	0.27	123	1.26	184	0.21	245	0.3	306	0.39	367	0.51
63	0.24	124	0.21	185	0.3	246	0.39	307	0.36	368	0.48
64	0.06	125	0.12	186	0.33	247	0.21	308	0.3	369	0.15
65	0.72	126	0.3	187	0.39	248	0.27	309	0.15	370	0.63
66	0.12	127	0.39	188	0.15	249	0.42	310	0.27	371	0.39
67	0.42	128	0.18	189	0.39	250	0.12	311	0.42	372	0.3
68	0.24	129	0.33	190	0.36	251	0.27	312	0.33	373	0.21
69	0.24	130	0.33	191	0.24	252	0.54	313	0.48	374	0.33
70	0.42	131	0.39	192	0.24	253	0.54	314	0.33	375	0.48
71	0.15	132	0.03	193	0.36	254	0.45	315	0.15	376	0.15
72	0.3	133	0.54	194	0.3	255	0.51	316	0.63	377	0.27
73	0.42	134	0.54	195	0.3	256	0.18	317	0.18	378	0.54
74	0.33	135	0.33	196	0.39	257	0.09	318	0.48	379	0.39
75	0.3	136	0.3	197	0.42	258	0.06	319	0.48	380	0.27
76	0.27	137	0.6	198	0.09	259	0.45	320	0.33	381	0.39
77	0.24	138	0.27	199	0.54	260	0.15	321	0.33	382	0.6
78	0.63	139	0.69	200	0.18	261	0.24	322	0.6	383	0.3
79	0.15	140	0.3	201	0.33	262	0.45	323	0.03	384	0.12
80	0.18	141	0.36	202	0.21	263	0.6	324	0.93	385	0.15
81	0.42	142	0.72	203	0.21	264	0.24	325	0.39		

Paediatrics:

Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours
21	0.42	82	0.33	143	0.45	204	0.48	265	0.06	326	0.3
22	0.27	83	1.02	144	1.53	205	0.84	266	0.51	327	0.15
23	0.42	84	0.84	145	0.3	206	0.57	267	0.84	328	0.42
24	0.93	85	0.24	146	0.3	207	0.21	268	0.57	329	0.51
25	1.32	86	0.39	147	0.27	208	0.33	269	0.72	330	0.69
26	0.81	87	0.33	148	0.27	209	0.36	270	0.6	331	0.42
27	0.66	88	0.57	149	0.57	210	0.33	271	0.51	332	0.57
28	0.42	89	0.87	150	0.6	211	0.15	272	0.24	333	0.36
29	0.48	90	0.45	151	0.42	212	0.42	273	0.57	334	0.72
30	0.3	91	0.3	152	0.39	213	0.72	274	0.69	335	0.3
31	0.24	92	0.66	153	0.99	214	0.54	275	0.48	336	1.14
32	0.66	93	0.72	154	0.33	215	0.24	276	0.18	337	0.54
33	0.42	94	0.39	155	0.18	216	0.66	277	0.81	338	0.24
34	0.84	95	0.66	156	0.48	217	0.72	278	0.12	339	0.42
35	0.3	96	0.18	157	0.39	218	0.06	279	0.27	340	0.54
36	0.54	97	0.81	158	0.66	219	0.42	280	0.42	341	0.81
37	0.18	98	0.09	159	0.39	220	0.3	281	0.48	342	0.63
38	0.9	99	0.84	160	0.72	221	0.66	282	0.36	343	0.24
39	0.69	100	0.6	161	0.3	222	0.6	283	0.42	344	0.45
40	0.57	101	0.33	162	0.84	223	0.6	284	0.72	345	0.96
41	0.69	102	0.48	163	0.15	224	0.45	285	0.42	346	0.45
42	0.42	103	0.3	164	0.39	225	0.66	286	0.72	347	0.42
43	0.51	104	0.15	165	0.63	226	0.57	287	0.78	348	0.51
44	0.78	105	0.57	166	0.6	227	0.54	288	0.36	349	0.39
45	0.21	106	0.9	167	0.24	228	0.09	289	0.66	350	0.84
46	0.42	107	0.39	168	0.3	229	0.63	290	0.75	351	0.3
47	0.48	108	0.36	169	0.48	230	0.57	291	0.39	352	1.11
48	0.12	109	0.45	170	0.48	231	0.33	292	0.27	353	0.09
49	0.45	110	0.21	171	1.17	232	0.75	293	0.39	354	0.36
50	0.63	111	1.05	172	0.36	233	0.51	294	0.36	355	0.3
51	0.54	112	0.45	173	0.24	234	0.27	295	0.81	356	0.18
52	0.39	113	0.51	174	1.23	235	0.6	296	0.78	357	0.48
53	0.06	114	0.21	175	0.72	236	0.24	297	0.42	358	0.6
54	0.6	115	0.87	176	0.78	237	0.72	298	0.48	359	0.21
55	1.02	116	0.45	177	0.15	238	0.84	299	0.18	360	0.66
56	0.42	117	0.69	178	0.45	239	0.3	300	0.3	361	0.6
57	0.48	118	0.75	179	0.39	240	0.36	301	0.6	362	0.54
58	0.24	119	0.48	180	0.6	241	0.15	302	0.36	363	0.12
59	0.54	120	0.63	181	0.45	242	0.54	303	1.17	364	0.3
60	0.96	121	0.42	182	0.18	243	0.6	304	0.18	365	1.32
61	0.72	122	0.33	183	0.96	244	0.42	305	0.69	366	0.36
62	0.18	123	0.42	184	0.63	245	0.3	306	0.51	367	0.66
63	0.12	124	0.51	185	0.6	246	1.02	307	0.12	368	1.29
64	0.48	125	0.3	186	0.15	247	0.18	308	0.45	369	0.21
65	1.26	126	1.05	187	0.93	248	0.57	309	0.51	370	0.06
66	0.66	127	0.51	188	0.72	249	0.33	310	0.81	371	0.27
67	0.36	128	0.42	189	0.27	250	0.24	311	0.57	372	0.54
68	0.57	129	0.63	190	0.51	251	0.87	312	0.42	373	0.57
69	0.75	130	0.57	191	0.93	252	0.93	313	0.21	374	0.66
70	0.33	131	0.69	192	0.84	253	0.24	314	0.51	375	0.57
71	0.69	132	0.24	193	0.33	254	0.63	315	0.36	376	0.57
72	0.57	133	0.24	194	0.42	255	0.39	316	0.51	377	0.15
73	0.51	134	0.27	195	0.24	256	0.06	317	0.36	378	0.6
74	0.69	135	0.45	196	0.51	257	0.57	318	1.05	379	1.74
75	0.27	136	0.6	197	0.39	258	0.27	319	0.24	380	0.36
76	0.48	137	0.75	198	0.27	259	1.17	320	0.27	381	0.78
77	0.51	138	0.45	199	0.72	260	0.33	321	0.36	382	0.63
78	0.27	139	0.6	200	0.63	261	0.84	322	0.48	383	0.36
79	0.33	140	0.6	201	0.36	262	0.24	323	0.45	384	0.39
80	0.27	141	0.45	202	0.87	263	0.03	324	0.15	385	0.27
81	0.87	142	0.54	203	0.21	264	1.14	325	0.87		

Emergency:

Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours
21	3.84	82	3.54	143	3.78	204	4.08	265	3.69	326	2.76
22	3.45	83	3.42	144	3.51	205	3.99	266	3.66	327	3.63
23	3.51	84	4.17	145	4.32	206	3.9	267	3.69	328	3.36
24	3.84	85	3.21	146	3.66	207	3.99	268	4.14	329	3.9
25	3.15	86	3.81	147	3.93	208	3.57	269	3.75	330	4.02
26	4.08	87	3.63	148	4.23	209	3.24	270	4.17	331	4.32
27	3.78	88	3.99	149	3.87	210	3.72	271	3.3	332	3.36
28	3.57	89	3.75	150	3.57	211	3.6	272	3.45	333	3.75
29	4.14	90	3.69	151	3.45	212	3.84	273	4.62	334	3.45
30	4.56	91	4.02	152	3.99	213	3.33	274	3.78	335	3.6
31	4.47	92	4.56	153	3.27	214	3.81	275	3.63	336	4.17
32	3.66	93	3.48	154	3.78	215	3.66	276	4.02	337	3.42
33	4.02	94	3.39	155	3.45	216	3.48	277	3.33	338	3.75
34	3.84	95	3	156	3.42	217	3.09	278	4.38	339	4.23
35	3.57	96	3.69	157	4.29	218	4.11	279	3.99	340	3.36
36	3.45	97	4.35	158	3.93	219	3.03	280	4.26	341	3.42
37	3.81	98	3.69	159	4.2	220	4.17	281	3.27	342	3.51
38	4.11	99	3.66	160	3.84	221	3.93	282	3.66	343	4.05
39	3.87	100	3.27	161	3.63	222	3.69	283	4.95	344	3.87
40	3.78	101	4.17	162	3.24	223	4.26	284	3.27	345	3.27
41	3.69	102	3.99	163	3.87	224	3.84	285	3.21	346	4.2
42	4.05	103	3.09	164	4.08	225	4.47	286	3.63	347	3.99
43	3.87	104	3.72	165	3.51	226	4.05	287	3.36	348	3.18
44	3.51	105	4.41	166	3.24	227	4.23	288	3.48	349	4.14
45	3.99	106	3.69	167	3.81	228	3.63	289	3.63	350	3.84
46	4.77	107	3.57	168	3.72	229	3.96	290	3.75	351	4.05
47	3.63	108	3.6	169	3.63	230	3.33	291	3.81	352	3.78
48	4.17	109	3.3	170	3.78	231	3.72	292	3.81	353	4.38
49	3.33	110	3.99	171	4.56	232	3.33	293	3.72	354	4.02
50	4.08	111	3.36	172	4.02	233	3.81	294	3.87	355	3.36
51	3.69	112	3.27	173	4.08	234	3.42	295	3.48	356	3.96
52	4.08	113	3.42	174	3.45	235	3.78	296	3.84	357	3.45
53	4.17	114	4.35	175	3.24	236	4.35	297	4.47	358	3.39
54	4.02	115	3.63	176	3.6	237	3.9	298	4.02	359	3.75
55	3.48	116	3.45	177	3.66	238	3.93	299	3.93	360	3.57
56	3.36	117	4.08	178	4.02	239	3.45	300	3.9	361	3.6
57	3.48	118	3.81	179	3.75	240	3.69	301	4.23	362	3.39
58	4.08	119	3.93	180	3.66	241	3.96	302	4.53	363	3.18
59	3.78	120	3.72	181	3.36	242	3.42	303	3.3	364	3.87
60	3.99	121	3.6	182	4.35	243	3.81	304	4.14	365	3.66
61	3.78	122	3.96	183	3.9	244	3.69	305	3.84	366	3.96
62	3.24	123	3.24	184	4.35	245	3.15	306	2.73	367	3.99
63	3.75	124	3.21	185	3.69	246	3.72	307	3.51	368	3.06
64	3.9	125	4.53	186	4.62	247	3.9	308	4.35	369	3.57
65	3.33	126	3.99	187	3.96	248	3.63	309	3.72	370	4.08
66	3.78	127	4.29	188	3.51	249	3.84	310	4.29	371	3.39
67	4.02	128	4.17	189	3.84	250	3.54	311	3.36	372	3.72
68	3.18	129	3.33	190	3.69	251	3.84	312	3.84	373	3.42
69	3.84	130	3.3	191	3.57	252	3.99	313	3.6	374	4.35
70	4.26	131	3.78	192	3.51	253	3.69	314	4.14	375	3.69
71	4.17	132	4.17	193	4.08	254	3.99	315	3.81	376	4.05
72	3.96	133	4.08	194	4.38	255	3.24	316	3.6	377	4.32
73	4.17	134	3.87	195	3.9	256	3.93	317	3.93	378	3.84
74	4.29	135	3.81	196	3.6	257	3.48	318	3.6	379	3.72
75	3.72	136	4.02	197	3.93	258	4.2	319	4.38	380	3.78
76	3.6	137	3.99	198	4.23	259	3.63	320	3.66	381	4.41
77	3.36	138	3.87	199	3.69	260	3.48	321	3.93	382	3.72
78	4.05	139	3.45	200	4.17	261	4.14	322	3.87	383	3.84
79	3.78	140	3.9	201	3.66	262	3.63	323	3.66	384	3.51
80	3.66	141	4.11	202	3.57	263	4.47	324	3.15	385	3.84
81	3.45	142	3.6	203	3.81	264	3.69	325	3.57		

Appendix I

Average Time (in Hours) Spent to Retrieve and Return Pumps per Day, by Department – Central Pooling System

CCU:

Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours
21	0.32	82	0.26	143	0.29	204	0.25	265	0.53	326	0.37
22	0.28	83	0.34	144	0.30	205	0.25	266	0.46	327	0.30
23	0.54	84	0.32	145	0.34	206	0.40	267	0.62	328	0.23
24	0.24	85	0.31	146	0.36	207	0.23	268	0.35	329	0.39
25	0.42	86	0.33	147	0.50	208	0.34	269	0.39	330	0.29
26	0.37	87	0.54	148	0.27	209	0.31	270	0.35	331	0.44
27	0.34	88	0.37	149	0.40	210	0.29	271	0.36	332	0.33
28	0.34	89	0.40	150	0.41	211	0.25	272	0.38	333	0.29
29	0.35	90	0.44	151	0.43	212	0.40	273	0.42	334	0.44
30	0.35	91	0.30	152	0.24	213	0.31	274	0.15	335	0.50
31	0.16	92	0.40	153	0.32	214	0.47	275	0.47	336	0.31
32	0.21	93	0.36	154	0.28	215	0.28	276	0.39	337	0.43
33	0.26	94	0.29	155	0.28	216	0.50	277	0.57	338	0.18
34	0.49	95	0.42	156	0.43	217	0.44	278	0.31	339	0.32
35	0.42	96	0.36	157	0.29	218	0.39	279	0.45	340	0.41
36	0.34	97	0.47	158	0.30	219	0.36	280	0.21	341	0.26
37	0.49	98	0.27	159	0.29	220	0.45	281	0.30	342	0.28
38	0.58	99	0.31	160	0.44	221	0.35	282	0.30	343	0.30
39	0.30	100	0.18	161	0.44	222	0.61	283	0.25	344	0.50
40	0.64	101	0.46	162	0.36	223	0.55	284	0.25	345	0.42
41	0.56	102	0.20	163	0.33	224	0.28	285	0.35	346	0.31
42	0.47	103	0.38	164	0.28	225	0.27	286	0.33	347	0.34
43	0.34	104	0.26	165	0.20	226	0.19	287	0.40	348	0.41
44	0.47	105	0.42	166	0.36	227	0.24	288	0.29	349	0.49
45	0.39	106	0.45	167	0.24	228	0.33	289	0.30	350	0.27
46	0.25	107	0.64	168	0.35	229	0.33	290	0.47	351	0.32
47	0.49	108	0.57	169	0.41	230	0.36	291	0.36	352	0.38
48	0.19	109	0.26	170	0.29	231	0.53	292	0.42	353	0.25
49	0.30	110	0.16	171	0.34	232	0.17	293	0.48	354	0.35
50	0.36	111	0.49	172	0.41	233	0.31	294	0.26	355	0.27
51	0.24	112	0.17	173	0.28	234	0.31	295	0.22	356	0.33
52	0.40	113	0.33	174	0.34	235	0.37	296	0.25	357	0.39
53	0.52	114	0.53	175	0.28	236	0.35	297	0.39	358	0.23
54	0.39	115	0.44	176	0.23	237	0.33	298	0.36	359	0.31
55	0.57	116	0.35	177	0.38	238	0.43	299	0.40	360	0.23
56	0.31	117	0.44	178	0.47	239	0.44	300	0.29	361	0.25
57	0.25	118	0.35	179	0.34	240	0.45	301	0.31	362	0.40
58	0.28	119	0.30	180	0.37	241	0.48	302	0.34	363	0.30
59	0.35	120	0.39	181	0.43	242	0.27	303	0.45	364	0.36
60	0.33	121	0.30	182	0.37	243	0.37	304	0.34	365	0.49
61	0.45	122	0.40	183	0.62	244	0.38	305	0.32	366	0.38
62	0.32	123	0.37	184	0.38	245	0.31	306	0.29	367	0.29
63	0.41	124	0.30	185	0.54	246	0.26	307	0.33	368	0.52
64	0.32	125	0.32	186	0.43	247	0.26	308	0.38	369	0.51
65	0.44	126	0.34	187	0.43	248	0.33	309	0.49	370	0.55
66	0.60	127	0.37	188	0.47	249	0.48	310	0.60	371	0.35
67	0.33	128	0.39	189	0.35	250	0.16	311	0.35	372	0.44
68	0.40	129	0.39	190	0.21	251	0.24	312	0.56	373	0.35
69	0.19	130	0.39	191	0.31	252	0.31	313	0.31	374	0.49
70	0.43	131	0.27	192	0.30	253	0.20	314	0.42	375	0.39
71	0.21	132	0.36	193	0.42	254	0.35	315	0.39	376	0.32
72	0.31	133	0.37	194	0.30	255	0.30	316	0.44	377	0.46
73	0.46	134	0.45	195	0.37	256	0.24	317	0.25	378	0.42
74	0.45	135	0.45	196	0.40	257	0.26	318	0.30	379	0.28
75	0.52	136	0.58	197	0.27	258	0.32	319	0.24	380	0.41
76	0.26	137	0.48	198	0.65	259	0.36	320	0.34	381	0.46
77	0.21	138	0.35	199	0.42	260	0.37	321	0.35	382	0.39
78	0.44	139	0.44	200	0.29	261	0.30	322	0.38	383	0.23
79	0.42	140	0.28	201	0.43	262	0.44	323	0.37	384	0.31
80	0.49	141	0.50	202	0.39	263	0.33	324	0.38	385	0.33
81	0.41	142	0.46	203	0.40	264	0.54	325	0.44		

General Surgery:

Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours
21	0.59	82	0.55	143	0.72	204	0.50	265	0.59	326	0.82
22	0.64	83	0.62	144	0.38	205	0.89	266	0.85	327	0.54
23	0.45	84	0.55	145	0.94	206	0.38	267	0.68	328	0.53
24	0.93	85	0.70	146	0.69	207	0.52	268	0.68	329	0.83
25	0.84	86	0.77	147	0.59	208	0.97	269	0.64	330	0.56
26	0.57	87	0.97	148	0.60	209	0.45	270	0.55	331	0.59
27	0.49	88	0.37	149	0.58	210	0.78	271	0.37	332	0.74
28	0.32	89	0.70	150	0.42	211	0.55	272	0.78	333	0.74
29	0.69	90	0.74	151	0.81	212	0.40	273	0.76	334	0.59
30	0.86	91	0.88	152	0.69	213	0.43	274	0.62	335	0.45
31	0.61	92	0.71	153	0.71	214	0.60	275	0.53	336	0.56
32	0.56	93	0.42	154	0.63	215	0.68	276	0.46	337	0.49
33	0.64	94	0.62	155	0.81	216	0.62	277	0.89	338	0.59
34	0.49	95	0.68	156	0.55	217	0.65	278	0.77	339	0.60
35	0.63	96	0.94	157	0.97	218	0.71	279	0.74	340	0.50
36	1.00	97	0.78	158	0.80	219	0.68	280	0.71	341	0.69
37	0.69	98	0.88	159	0.67	220	0.77	281	0.48	342	0.50
38	0.57	99	0.80	160	0.67	221	0.57	282	0.70	343	0.71
39	0.60	100	0.59	161	0.40	222	0.70	283	0.66	344	0.53
40	0.61	101	0.43	162	0.40	223	0.79	284	0.86	345	0.66
41	0.73	102	0.71	163	0.56	224	0.62	285	0.68	346	0.65
42	0.90	103	0.71	164	0.68	225	0.43	286	0.65	347	0.76
43	0.57	104	0.63	165	0.53	226	0.45	287	0.81	348	0.48
44	0.88	105	0.58	166	0.65	227	0.68	288	0.55	349	0.81
45	0.59	106	0.77	167	0.49	228	0.40	289	0.41	350	0.58
46	0.76	107	0.62	168	0.65	229	0.62	290	0.27	351	0.50
47	0.66	108	0.73	169	0.53	230	0.76	291	0.74	352	0.47
48	0.55	109	0.55	170	0.63	231	0.38	292	0.55	353	0.35
49	0.44	110	0.37	171	0.64	232	0.61	293	0.53	354	0.83
50	0.61	111	0.48	172	0.52	233	0.60	294	0.78	355	0.64
51	0.56	112	0.47	173	0.57	234	0.40	295	0.48	356	0.78
52	0.64	113	0.74	174	0.91	235	0.59	296	0.53	357	0.44
53	0.62	114	0.75	175	0.68	236	0.37	297	0.47	358	0.59
54	0.77	115	0.64	176	0.45	237	0.42	298	0.66	359	0.50
55	0.62	116	0.52	177	0.66	238	0.66	299	0.61	360	0.44
56	0.52	117	0.78	178	0.87	239	0.67	300	0.38	361	0.86
57	0.50	118	0.52	179	0.39	240	0.69	301	0.44	362	1.13
58	0.85	119	0.67	180	0.90	241	0.59	302	0.84	363	0.59
59	0.93	120	0.50	181	0.55	242	0.73	303	0.54	364	0.61
60	0.55	121	0.67	182	0.82	243	0.43	304	0.70	365	0.62
61	0.55	122	0.90	183	0.78	244	0.72	305	0.67	366	0.73
62	1.00	123	1.03	184	0.89	245	0.74	306	0.67	367	0.82
63	0.80	124	0.69	185	0.52	246	0.71	307	0.74	368	0.53
64	0.67	125	0.42	186	0.44	247	0.63	308	0.71	369	0.57
65	0.82	126	0.70	187	0.53	248	0.67	309	0.52	370	0.65
66	0.56	127	0.63	188	0.57	249	0.47	310	0.53	371	0.70
67	0.48	128	0.74	189	0.73	250	0.61	311	0.54	372	0.66
68	0.56	129	0.50	190	0.62	251	0.41	312	0.71	373	0.81
69	0.66	130	0.63	191	0.36	252	1.02	313	0.89	374	0.69
70	0.56	131	0.60	192	0.74	253	0.79	314	0.61	375	0.64
71	0.71	132	0.61	193	0.79	254	0.69	315	0.46	376	0.46
72	0.51	133	0.95	194	0.55	255	0.40	316	0.46	377	0.95
73	0.75	134	0.77	195	0.69	256	0.69	317	0.51	378	0.34
74	0.71	135	0.48	196	0.53	257	0.42	318	0.60	379	0.54
75	0.52	136	0.75	197	0.76	258	0.61	319	0.45	380	0.65
76	0.44	137	0.54	198	0.90	259	0.63	320	0.59	381	0.57
77	0.53	138	0.58	199	0.68	260	0.54	321	0.57	382	0.64
78	0.58	139	0.60	200	0.50	261	0.59	322	0.89	383	0.48
79	0.63	140	0.73	201	0.83	262	0.64	323	0.91	384	0.42
80	0.70	141	0.66	202	0.67	263	0.62	324	0.76	385	0.67
81	0.67	142	0.67	203	0.58	264	0.44	325	0.58		

ICU:

Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours
21	0.43	82	0.55	143	0.44	204	0.52	265	0.85	326	0.68
22	0.82	83	0.66	144	0.68	205	0.87	266	0.95	327	0.54
23	0.85	84	0.84	145	0.99	206	0.84	267	0.89	328	0.76
24	0.89	85	0.57	146	0.90	207	0.89	268	0.77	329	0.72
25	0.59	86	0.81	147	0.70	208	0.72	269	0.49	330	0.68
26	0.65	87	0.61	148	1.07	209	0.73	270	0.80	331	1.02
27	0.61	88	0.63	149	0.85	210	0.83	271	0.62	332	0.88
28	1.01	89	0.65	150	0.59	211	1.02	272	0.89	333	0.95
29	0.45	90	0.87	151	0.56	212	0.67	273	0.81	334	0.59
30	0.75	91	0.69	152	0.91	213	0.78	274	1.19	335	0.57
31	0.69	92	0.72	153	0.92	214	0.89	275	0.72	336	0.92
32	0.74	93	0.67	154	0.43	215	0.91	276	1.06	337	0.79
33	0.74	94	0.65	155	0.47	216	0.65	277	0.89	338	1.18
34	1.00	95	0.70	156	0.87	217	0.77	278	0.74	339	0.85
35	0.67	96	0.70	157	0.20	218	0.87	279	0.60	340	0.74
36	1.05	97	0.54	158	0.70	219	1.13	280	1.06	341	0.71
37	0.68	98	0.77	159	0.55	220	0.61	281	0.44	342	0.96
38	0.59	99	0.81	160	0.66	221	0.73	282	0.82	343	0.90
39	0.87	100	0.48	161	0.81	222	0.93	283	0.92	344	0.55
40	0.76	101	0.39	162	0.66	223	0.75	284	0.83	345	0.42
41	0.75	102	0.68	163	0.74	224	0.81	285	0.38	346	0.74
42	0.52	103	0.86	164	0.66	225	0.50	286	0.62	347	0.90
43	0.80	104	0.49	165	0.68	226	0.33	287	0.87	348	0.40
44	0.67	105	0.48	166	0.67	227	0.44	288	0.41	349	0.53
45	0.56	106	1.05	167	0.46	228	0.63	289	0.62	350	0.75
46	0.89	107	0.81	168	0.74	229	0.64	290	0.81	351	0.77
47	0.92	108	0.88	169	0.65	230	0.51	291	1.11	352	0.75
48	0.68	109	0.81	170	0.50	231	0.88	292	0.51	353	0.77
49	0.79	110	0.80	171	0.82	232	0.45	293	0.69	354	0.76
50	0.45	111	0.56	172	0.91	233	0.83	294	0.34	355	0.64
51	0.72	112	0.68	173	0.55	234	0.65	295	0.66	356	1.00
52	0.74	113	0.54	174	0.61	235	0.92	296	0.61	357	0.77
53	0.82	114	0.79	175	0.77	236	0.33	297	0.69	358	0.60
54	0.73	115	1.06	176	0.71	237	0.60	298	1.54	359	0.88
55	0.98	116	0.88	177	0.56	238	0.63	299	0.75	360	0.69
56	0.73	117	0.85	178	0.77	239	0.71	300	0.71	361	0.34
57	0.64	118	0.69	179	0.81	240	1.10	301	0.77	362	0.95
58	0.43	119	0.59	180	0.70	241	0.51	302	0.61	363	0.66
59	0.71	120	0.77	181	0.73	242	0.98	303	0.70	364	0.65
60	0.63	121	0.48	182	0.92	243	0.82	304	0.78	365	0.90
61	0.83	122	0.77	183	0.76	244	0.55	305	0.84	366	0.78
62	0.90	123	0.79	184	0.98	245	0.71	306	0.50	367	0.94
63	0.61	124	0.73	185	0.84	246	0.73	307	0.37	368	0.63
64	0.58	125	0.89	186	0.59	247	0.68	308	0.32	369	0.89
65	0.57	126	1.00	187	0.55	248	1.06	309	0.74	370	0.51
66	0.93	127	0.57	188	0.76	249	0.71	310	0.87	371	0.44
67	0.80	128	0.68	189	1.21	250	0.50	311	0.53	372	0.81
68	0.69	129	0.47	190	1.12	251	0.80	312	0.60	373	0.98
69	0.53	130	0.83	191	0.89	252	0.83	313	0.61	374	0.50
70	0.58	131	0.76	192	0.81	253	0.93	314	1.09	375	0.55
71	0.51	132	1.09	193	0.45	254	0.88	315	1.07	376	0.66
72	0.76	133	0.82	194	0.61	255	0.69	316	1.12	377	0.81
73	0.62	134	0.72	195	0.50	256	1.03	317	0.63	378	0.60
74	0.97	135	1.21	196	0.87	257	0.97	318	0.76	379	0.68
75	1.01	136	0.68	197	0.61	258	0.91	319	0.76	380	0.90
76	0.63	137	0.59	198	0.77	259	0.57	320	0.48	381	0.57
77	0.67	138	0.80	199	0.57	260	0.80	321	0.82	382	0.88
78	0.77	139	0.87	200	0.32	261	0.73	322	1.04	383	0.47
79	0.59	140	0.90	201	0.65	262	0.75	323	0.91	384	0.96
80	0.76	141	0.69	202	0.57	263	0.95	324	0.75	385	0.64
81	0.86	142	1.07	203	0.54	264	0.86	325	0.64		

Medical Program:

Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours
21	0.34	82	0.28	143	0.39	204	0.20	265	0.22	326	0.38
22	0.25	83	0.30	144	0.29	205	0.38	266	0.27	327	0.36
23	0.28	84	0.46	145	0.29	206	0.44	267	0.27	328	0.30
24	0.21	85	0.33	146	0.33	207	0.31	268	0.10	329	0.34
25	0.41	86	0.30	147	0.29	208	0.26	269	0.34	330	0.28
26	0.40	87	0.21	148	0.21	209	0.33	270	0.13	331	0.31
27	0.27	88	0.34	149	0.45	210	0.29	271	0.31	332	0.24
28	0.30	89	0.29	150	0.33	211	0.34	272	0.30	333	0.30
29	0.37	90	0.27	151	0.34	212	0.45	273	0.23	334	0.34
30	0.51	91	0.26	152	0.40	213	0.35	274	0.37	335	0.25
31	0.49	92	0.33	153	0.29	214	0.31	275	0.37	336	0.42
32	0.27	93	0.39	154	0.33	215	0.38	276	0.32	337	0.26
33	0.33	94	0.22	155	0.27	216	0.32	277	0.44	338	0.24
34	0.30	95	0.25	156	0.17	217	0.46	278	0.35	339	0.25
35	0.32	96	0.35	157	0.31	218	0.33	279	0.30	340	0.38
36	0.35	97	0.37	158	0.28	219	0.32	280	0.27	341	0.34
37	0.30	98	0.34	159	0.34	220	0.34	281	0.25	342	0.35
38	0.25	99	0.33	160	0.30	221	0.21	282	0.39	343	0.14
39	0.37	100	0.41	161	0.26	222	0.38	283	0.46	344	0.28
40	0.36	101	0.26	162	0.31	223	0.35	284	0.30	345	0.38
41	0.29	102	0.24	163	0.28	224	0.26	285	0.26	346	0.44
42	0.33	103	0.34	164	0.39	225	0.30	286	0.26	347	0.34
43	0.37	104	0.32	165	0.19	226	0.32	287	0.36	348	0.27
44	0.44	105	0.30	166	0.16	227	0.28	288	0.36	349	0.33
45	0.28	106	0.35	167	0.32	228	0.36	289	0.38	350	0.28
46	0.19	107	0.23	168	0.31	229	0.19	290	0.37	351	0.37
47	0.35	108	0.20	169	0.55	230	0.33	291	0.21	352	0.26
48	0.21	109	0.31	170	0.31	231	0.21	292	0.27	353	0.26
49	0.31	110	0.29	171	0.38	232	0.41	293	0.40	354	0.51
50	0.41	111	0.32	172	0.42	233	0.47	294	0.36	355	0.41
51	0.31	112	0.23	173	0.30	234	0.36	295	0.20	356	0.29
52	0.45	113	0.17	174	0.24	235	0.37	296	0.32	357	0.37
53	0.28	114	0.36	175	0.28	236	0.42	297	0.40	358	0.28
54	0.31	115	0.24	176	0.21	237	0.30	298	0.61	359	0.17
55	0.21	116	0.45	177	0.25	238	0.23	299	0.54	360	0.31
56	0.38	117	0.31	178	0.26	239	0.14	300	0.32	361	0.29
57	0.35	118	0.34	179	0.40	240	0.22	301	0.19	362	0.19
58	0.32	119	0.49	180	0.30	241	0.22	302	0.24	363	0.33
59	0.24	120	0.27	181	0.48	242	0.38	303	0.20	364	0.30
60	0.31	121	0.34	182	0.38	243	0.26	304	0.26	365	0.26
61	0.25	122	0.39	183	0.31	244	0.30	305	0.39	366	0.25
62	0.33	123	0.35	184	0.33	245	0.32	306	0.35	367	0.44
63	0.35	124	0.42	185	0.36	246	0.41	307	0.33	368	0.40
64	0.35	125	0.32	186	0.34	247	0.45	308	0.32	369	0.31
65	0.26	126	0.39	187	0.35	248	0.32	309	0.25	370	0.30
66	0.30	127	0.30	188	0.31	249	0.28	310	0.32	371	0.29
67	0.32	128	0.26	189	0.25	250	0.41	311	0.34	372	0.26
68	0.22	129	0.31	190	0.21	251	0.25	312	0.32	373	0.20
69	0.34	130	0.37	191	0.21	252	0.21	313	0.34	374	0.31
70	0.28	131	0.37	192	0.26	253	0.36	314	0.31	375	0.39
71	0.24	132	0.35	193	0.33	254	0.47	315	0.15	376	0.30
72	0.37	133	0.55	194	0.40	255	0.36	316	0.23	377	0.23
73	0.19	134	0.27	195	0.44	256	0.50	317	0.19	378	0.37
74	0.41	135	0.33	196	0.38	257	0.22	318	0.32	379	0.29
75	0.35	136	0.20	197	0.29	258	0.29	319	0.40	380	0.19
76	0.17	137	0.27	198	0.20	259	0.32	320	0.54	381	0.17
77	0.36	138	0.41	199	0.29	260	0.35	321	0.38	382	0.37
78	0.30	139	0.35	200	0.30	261	0.26	322	0.40	383	0.26
79	0.33	140	0.32	201	0.27	262	0.25	323	0.55	384	0.31
80	0.24	141	0.42	202	0.31	263	0.43	324	0.41	385	0.29
81	0.21	142	0.53	203	0.23	264	0.35	325	0.31		

Oncology:

Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours
21	0.31	82	0.16	143	0.31	204	0.32	265	0.23	326	0.23
22	0.25	83	0.31	144	0.20	205	0.15	266	0.19	327	0.22
23	0.34	84	0.22	145	0.19	206	0.30	267	0.17	328	0.18
24	0.33	85	0.28	146	0.19	207	0.19	268	0.26	329	0.27
25	0.28	86	0.21	147	0.21	208	0.30	269	0.25	330	0.32
26	0.23	87	0.17	148	0.10	209	0.23	270	0.41	331	0.14
27	0.36	88	0.24	149	0.28	210	0.13	271	0.31	332	0.19
28	0.22	89	0.10	150	0.18	211	0.19	272	0.26	333	0.19
29	0.30	90	0.19	151	0.18	212	0.16	273	0.43	334	0.15
30	0.18	91	0.25	152	0.25	213	0.20	274	0.19	335	0.31
31	0.14	92	0.19	153	0.24	214	0.22	275	0.20	336	0.26
32	0.35	93	0.19	154	0.22	215	0.14	276	0.20	337	0.20
33	0.36	94	0.20	155	0.16	216	0.27	277	0.31	338	0.20
34	0.31	95	0.16	156	0.16	217	0.32	278	0.28	339	0.20
35	0.09	96	0.21	157	0.33	218	0.22	279	0.20	340	0.28
36	0.25	97	0.19	158	0.24	219	0.29	280	0.19	341	0.37
37	0.17	98	0.19	159	0.25	220	0.28	281	0.13	342	0.18
38	0.22	99	0.33	160	0.16	221	0.16	282	0.13	343	0.24
39	0.43	100	0.27	161	0.16	222	0.31	283	0.35	344	0.14
40	0.16	101	0.26	162	0.24	223	0.38	284	0.27	345	0.22
41	0.26	102	0.24	163	0.19	224	0.23	285	0.25	346	0.17
42	0.18	103	0.22	164	0.28	225	0.35	286	0.28	347	0.19
43	0.23	104	0.23	165	0.32	226	0.26	287	0.30	348	0.27
44	0.37	105	0.27	166	0.29	227	0.19	288	0.25	349	0.29
45	0.26	106	0.22	167	0.28	228	0.16	289	0.20	350	0.23
46	0.35	107	0.18	168	0.22	229	0.31	290	0.20	351	0.17
47	0.23	108	0.25	169	0.13	230	0.26	291	0.28	352	0.17
48	0.25	109	0.18	170	0.26	231	0.27	292	0.20	353	0.15
49	0.31	110	0.22	171	0.33	232	0.15	293	0.18	354	0.25
50	0.17	111	0.16	172	0.28	233	0.18	294	0.34	355	0.21
51	0.22	112	0.21	173	0.23	234	0.24	295	0.28	356	0.20
52	0.20	113	0.26	174	0.24	235	0.18	296	0.30	357	0.19
53	0.12	114	0.15	175	0.30	236	0.39	297	0.19	358	0.24
54	0.26	115	0.27	176	0.21	237	0.18	298	0.20	359	0.26
55	0.39	116	0.28	177	0.18	238	0.15	299	0.17	360	0.12
56	0.26	117	0.19	178	0.23	239	0.20	300	0.24	361	0.22
57	0.15	118	0.13	179	0.12	240	0.25	301	0.27	362	0.18
58	0.14	119	0.25	180	0.21	241	0.25	302	0.24	363	0.15
59	0.21	120	0.20	181	0.21	242	0.11	303	0.21	364	0.35
60	0.14	121	0.24	182	0.27	243	0.13	304	0.23	365	0.33
61	0.19	122	0.44	183	0.25	244	0.16	305	0.26	366	0.32
62	0.21	123	0.44	184	0.16	245	0.19	306	0.17	367	0.27
63	0.13	124	0.18	185	0.14	246	0.19	307	0.25	368	0.18
64	0.29	125	0.16	186	0.25	247	0.21	308	0.26	369	0.27
65	0.32	126	0.19	187	0.23	248	0.20	309	0.30	370	0.33
66	0.22	127	0.21	188	0.13	249	0.19	310	0.25	371	0.18
67	0.25	128	0.24	189	0.21	250	0.25	311	0.22	372	0.25
68	0.15	129	0.21	190	0.13	251	0.13	312	0.24	373	0.20
69	0.23	130	0.26	191	0.27	252	0.22	313	0.21	374	0.24
70	0.24	131	0.23	192	0.26	253	0.23	314	0.20	375	0.20
71	0.19	132	0.19	193	0.19	254	0.29	315	0.13	376	0.21
72	0.22	133	0.32	194	0.23	255	0.28	316	0.28	377	0.18
73	0.20	134	0.34	195	0.22	256	0.15	317	0.26	378	0.27
74	0.26	135	0.23	196	0.20	257	0.08	318	0.25	379	0.27
75	0.31	136	0.29	197	0.23	258	0.13	319	0.25	380	0.29
76	0.23	137	0.28	198	0.10	259	0.24	320	0.18	381	0.24
77	0.24	138	0.14	199	0.33	260	0.22	321	0.21	382	0.27
78	0.25	139	0.31	200	0.20	261	0.18	322	0.24	383	0.27
79	0.23	140	0.25	201	0.17	262	0.33	323	0.41	384	0.18
80	0.18	141	0.26	202	0.27	263	0.32	324	0.37	385	0.17
81	0.28	142	0.30	203	0.21	264	0.16	325	0.29		

Paediatrics:

Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours
21	0.32	82	0.44	143	0.33	204	0.29	265	0.30	326	0.30
22	0.34	83	0.43	144	0.54	205	0.40	266	0.38	327	0.13
23	0.35	84	0.44	145	0.30	206	0.29	267	0.41	328	0.37
24	0.40	85	0.26	146	0.26	207	0.16	268	0.32	329	0.38
25	0.60	86	0.33	147	0.34	208	0.22	269	0.35	330	0.28
26	0.43	87	0.20	148	0.36	209	0.25	270	0.48	331	0.45
27	0.40	88	0.30	149	0.31	210	0.21	271	0.33	332	0.31
28	0.34	89	0.44	150	0.47	211	0.29	272	0.24	333	0.35
29	0.32	90	0.36	151	0.32	212	0.31	273	0.44	334	0.26
30	0.34	91	0.37	152	0.29	213	0.43	274	0.38	335	0.43
31	0.17	92	0.32	153	0.40	214	0.31	275	0.32	336	0.55
32	0.35	93	0.35	154	0.42	215	0.25	276	0.17	337	0.35
33	0.32	94	0.28	155	0.29	216	0.42	277	0.27	338	0.24
34	0.40	95	0.31	156	0.31	217	0.26	278	0.23	339	0.25
35	0.39	96	0.45	157	0.34	218	0.36	279	0.39	340	0.29
36	0.28	97	0.49	158	0.30	219	0.29	280	0.23	341	0.49
37	0.27	98	0.38	159	0.23	220	0.25	281	0.31	342	0.32
38	0.52	99	0.37	160	0.31	221	0.38	282	0.37	343	0.24
39	0.59	100	0.31	161	0.20	222	0.24	283	0.34	344	0.41
40	0.27	101	0.27	162	0.38	223	0.35	284	0.39	345	0.47
41	0.26	102	0.31	163	0.35	224	0.39	285	0.30	346	0.32
42	0.33	103	0.18	164	0.35	225	0.45	286	0.35	347	0.22
43	0.41	104	0.29	165	0.47	226	0.30	287	0.36	348	0.21
44	0.44	105	0.41	166	0.21	227	0.25	288	0.25	349	0.35
45	0.20	106	0.34	167	0.36	228	0.27	289	0.29	350	0.42
46	0.33	107	0.26	168	0.23	229	0.38	290	0.53	351	0.41
47	0.27	108	0.18	169	0.34	230	0.31	291	0.36	352	0.50
48	0.19	109	0.39	170	0.39	231	0.23	292	0.30	353	0.24
49	0.31	110	0.39	171	0.50	232	0.49	293	0.32	354	0.28
50	0.45	111	0.41	172	0.22	233	0.34	294	0.37	355	0.31
51	0.28	112	0.41	173	0.45	234	0.32	295	0.50	356	0.33
52	0.20	113	0.37	174	0.55	235	0.24	296	0.30	357	0.41
53	0.27	114	0.35	175	0.44	236	0.42	297	0.29	358	0.28
54	0.29	115	0.36	176	0.34	237	0.40	298	0.30	359	0.23
55	0.59	116	0.35	177	0.25	238	0.35	299	0.37	360	0.36
56	0.41	117	0.45	178	0.39	239	0.35	300	0.25	361	0.45
57	0.40	118	0.41	179	0.35	240	0.26	301	0.33	362	0.32
58	0.27	119	0.29	180	0.38	241	0.16	302	0.30	363	0.14
59	0.26	120	0.26	181	0.21	242	0.30	303	0.42	364	0.39
60	0.58	121	0.45	182	0.37	243	0.33	304	0.33	365	0.49
61	0.48	122	0.17	183	0.45	244	0.38	305	0.26	366	0.36
62	0.19	123	0.20	184	0.36	245	0.21	306	0.29	367	0.49
63	0.29	124	0.32	185	0.32	246	0.39	307	0.38	368	0.45
64	0.24	125	0.24	186	0.44	247	0.25	308	0.22	369	0.22
65	0.51	126	0.46	187	0.39	248	0.25	309	0.42	370	0.30
66	0.38	127	0.46	188	0.37	249	0.42	310	0.35	371	0.24
67	0.45	128	0.26	189	0.34	250	0.32	311	0.25	372	0.36
68	0.29	129	0.37	190	0.36	251	0.58	312	0.30	373	0.32
69	0.44	130	0.40	191	0.42	252	0.42	313	0.15	374	0.33
70	0.34	131	0.31	192	0.35	253	0.28	314	0.30	375	0.50
71	0.61	132	0.40	193	0.36	254	0.27	315	0.36	376	0.53
72	0.35	133	0.34	194	0.34	255	0.19	316	0.31	377	0.28
73	0.28	134	0.28	195	0.30	256	0.41	317	0.27	378	0.45
74	0.30	135	0.29	196	0.38	257	0.22	318	0.42	379	0.62
75	0.21	136	0.33	197	0.24	258	0.47	319	0.32	380	0.34
76	0.33	137	0.35	198	0.25	259	0.44	320	0.14	381	0.47
77	0.30	138	0.32	199	0.35	260	0.34	321	0.41	382	0.46
78	0.40	139	0.34	200	0.51	261	0.40	322	0.32	383	0.32
79	0.36	140	0.23	201	0.36	262	0.23	323	0.29	384	0.27
80	0.20	141	0.36	202	0.35	263	0.20	324	0.29	385	0.24
81	0.39	142	0.48	203	0.33	264	0.43	325	0.43		

Emergency:

Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours
21	1.28	82	1.18	143	1.26	204	1.36	265	1.23	326	0.92
22	1.15	83	1.14	144	1.17	205	1.33	266	1.22	327	1.21
23	1.17	84	1.39	145	1.44	206	1.30	267	1.23	328	1.12
24	1.28	85	1.07	146	1.22	207	1.33	268	1.38	329	1.30
25	1.05	86	1.27	147	1.31	208	1.19	269	1.25	330	1.34
26	1.36	87	1.21	148	1.41	209	1.08	270	1.39	331	1.44
27	1.26	88	1.33	149	1.29	210	1.24	271	1.10	332	1.12
28	1.19	89	1.25	150	1.19	211	1.20	272	1.15	333	1.25
29	1.38	90	1.23	151	1.15	212	1.28	273	1.54	334	1.15
30	1.52	91	1.34	152	1.33	213	1.11	274	1.26	335	1.20
31	1.49	92	1.52	153	1.09	214	1.27	275	1.21	336	1.39
32	1.22	93	1.16	154	1.26	215	1.22	276	1.34	337	1.14
33	1.34	94	1.13	155	1.15	216	1.16	277	1.11	338	1.25
34	1.28	95	1.00	156	1.14	217	1.03	278	1.46	339	1.41
35	1.19	96	1.23	157	1.43	218	1.37	279	1.33	340	1.12
36	1.15	97	1.45	158	1.31	219	1.01	280	1.42	341	1.14
37	1.27	98	1.23	159	1.40	220	1.39	281	1.09	342	1.17
38	1.37	99	1.22	160	1.28	221	1.31	282	1.22	343	1.35
39	1.29	100	1.09	161	1.21	222	1.23	283	1.65	344	1.29
40	1.26	101	1.39	162	1.08	223	1.42	284	1.09	345	1.09
41	1.23	102	1.33	163	1.29	224	1.28	285	1.07	346	1.40
42	1.35	103	1.03	164	1.36	225	1.49	286	1.21	347	1.33
43	1.29	104	1.24	165	1.17	226	1.35	287	1.12	348	1.06
44	1.17	105	1.47	166	1.08	227	1.41	288	1.16	349	1.38
45	1.33	106	1.23	167	1.27	228	1.21	289	1.21	350	1.28
46	1.59	107	1.19	168	1.24	229	1.32	290	1.25	351	1.35
47	1.21	108	1.20	169	1.21	230	1.11	291	1.27	352	1.26
48	1.39	109	1.10	170	1.26	231	1.24	292	1.27	353	1.46
49	1.11	110	1.33	171	1.52	232	1.11	293	1.24	354	1.34
50	1.36	111	1.12	172	1.34	233	1.27	294	1.29	355	1.12
51	1.23	112	1.09	173	1.36	234	1.14	295	1.16	356	1.32
52	1.36	113	1.14	174	1.15	235	1.26	296	1.28	357	1.15
53	1.39	114	1.45	175	1.08	236	1.45	297	1.49	358	1.13
54	1.34	115	1.21	176	1.20	237	1.30	298	1.34	359	1.25
55	1.16	116	1.15	177	1.22	238	1.31	299	1.31	360	1.19
56	1.12	117	1.36	178	1.34	239	1.15	300	1.30	361	1.20
57	1.16	118	1.27	179	1.25	240	1.23	301	1.41	362	1.13
58	1.36	119	1.31	180	1.22	241	1.32	302	1.51	363	1.06
59	1.26	120	1.24	181	1.12	242	1.14	303	1.10	364	1.29
60	1.33	121	1.20	182	1.45	243	1.27	304	1.38	365	1.22
61	1.26	122	1.32	183	1.30	244	1.23	305	1.28	366	1.32
62	1.08	123	1.08	184	1.45	245	1.05	306	0.91	367	1.33
63	1.25	124	1.07	185	1.23	246	1.24	307	1.17	368	1.02
64	1.30	125	1.51	186	1.54	247	1.30	308	1.45	369	1.19
65	1.11	126	1.33	187	1.32	248	1.21	309	1.24	370	1.36
66	1.26	127	1.43	188	1.17	249	1.28	310	1.43	371	1.13
67	1.34	128	1.39	189	1.28	250	1.18	311	1.12	372	1.24
68	1.06	129	1.11	190	1.23	251	1.28	312	1.28	373	1.14
69	1.28	130	1.10	191	1.19	252	1.33	313	1.20	374	1.45
70	1.42	131	1.26	192	1.17	253	1.23	314	1.38	375	1.23
71	1.39	132	1.39	193	1.36	254	1.33	315	1.27	376	1.35
72	1.32	133	1.36	194	1.46	255	1.08	316	1.20	377	1.44
73	1.39	134	1.29	195	1.30	256	1.31	317	1.31	378	1.28
74	1.43	135	1.27	196	1.20	257	1.16	318	1.20	379	1.24
75	1.24	136	1.34	197	1.31	258	1.40	319	1.46	380	1.26
76	1.20	137	1.33	198	1.41	259	1.21	320	1.22	381	1.47
77	1.12	138	1.29	199	1.23	260	1.16	321	1.31	382	1.24
78	1.35	139	1.15	200	1.39	261	1.38	322	1.29	383	1.28
79	1.26	140	1.30	201	1.22	262	1.21	323	1.22	384	1.17
80	1.22	141	1.37	202	1.19	263	1.49	324	1.05	385	1.28
81	1.15	142	1.20	203	1.27	264	1.23	325	1.19		

Appendix J

Numbers of Pumps to Maintain in the System to Meet Service Levels between 0% and 100% – 10 Replications

Replication 1:

# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)
98	.27%	124	15.57%	150	62.84%	176	94.81%
99	.55%	125	17.49%	151	65.03%	177	95.08%
100	.55%	126	17.76%	152	67.21%	178	95.90%
101	.55%	127	18.85%	153	69.95%	179	95.90%
102	.55%	128	19.40%	154	72.13%	180	96.72%
103	.82%	129	21.58%	155	73.50%	181	96.99%
104	.82%	130	23.50%	156	76.50%	182	97.54%
105	.82%	131	24.59%	157	77.87%	183	97.81%
106	1.91%	132	26.78%	158	78.96%	184	98.63%
107	2.19%	133	28.14%	159	80.33%	185	98.63%
108	2.19%	134	29.78%	160	81.97%	186	98.63%
109	2.46%	135	32.51%	161	83.88%	187	99.45%
110	2.46%	136	33.88%	162	84.97%	188	99.45%
111	3.01%	137	37.43%	163	85.79%	189	99.73%
112	3.28%	138	38.80%	164	85.79%	190	99.73%
113	3.83%	139	39.89%	165	87.43%	191	99.73%
114	4.10%	140	41.80%	166	88.52%	192	99.73%
115	4.10%	141	42.62%	167	90.16%	193	99.73%
116	4.37%	142	44.26%	168	90.44%	194	99.73%
117	5.74%	143	47.54%	169	90.71%	195	99.73%
118	7.65%	144	48.91%	170	91.53%	196	99.73%
119	8.20%	145	51.37%	171	91.80%	197	99.73%
120	9.56%	146	53.01%	172	92.90%	198	100.00%
121	10.93%	147	54.37%	173	92.90%		
122	12.30%	148	57.10%	174	93.17%		
123	14.75%	149	59.56%	175	93.72%		

Replication 2:

# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)
89	.27%	115	6.56%	141	42.08%	167	91.53%
90	.27%	116	6.83%	142	43.72%	168	92.62%
91	.27%	117	7.65%	143	46.45%	169	93.17%
92	.27%	118	8.20%	144	47.54%	170	94.26%
93	.27%	119	9.29%	145	49.18%	171	94.81%
94	.27%	120	9.56%	146	51.09%	172	95.90%
95	.27%	121	10.93%	147	55.74%	173	96.45%
96	.27%	122	12.30%	148	58.47%	174	97.27%
97	.55%	123	13.11%	149	61.20%	175	97.81%
98	.82%	124	13.11%	150	63.39%	176	97.81%
99	.82%	125	13.93%	151	65.30%	177	97.81%
100	1.09%	126	14.75%	152	66.67%	178	97.81%
101	1.09%	127	16.12%	153	69.40%	179	97.81%
102	1.09%	128	17.49%	154	71.04%	180	98.09%
103	1.09%	129	18.31%	155	74.32%	181	98.63%
104	1.64%	130	21.86%	156	75.68%	182	99.18%
105	1.64%	131	23.77%	157	77.60%	183	99.18%
106	1.91%	132	26.23%	158	78.96%	184	99.45%
107	2.73%	133	27.05%	159	80.60%	185	99.45%
108	2.73%	134	28.42%	160	81.97%	186	99.73%
109	3.01%	135	30.60%	161	83.33%	187	99.73%
110	3.55%	136	31.97%	162	84.97%	188	99.73%
111	4.10%	137	33.06%	163	86.89%	189	99.73%
112	4.64%	138	34.70%	164	88.80%	190	99.73%
113	5.19%	139	37.16%	165	89.62%	191	99.73%
114	6.56%	140	40.71%	166	90.71%	192	100.00%

Replication 3:

# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)
97	.55%	124	19.13%	151	66.94%	178	96.72%
98	.55%	125	19.67%	152	67.76%	179	96.72%
99	.82%	126	20.49%	153	70.77%	180	97.27%
100	.82%	127	21.31%	154	72.68%	181	97.54%
101	.82%	128	24.04%	155	74.59%	182	97.81%
102	.82%	129	26.23%	156	75.68%	183	98.63%
103	.82%	130	28.42%	157	77.32%	184	98.63%
104	1.09%	131	30.60%	158	78.96%	185	99.18%
105	1.09%	132	33.61%	159	80.87%	186	99.18%
106	1.09%	133	34.97%	160	82.24%	187	99.45%
107	1.09%	134	37.70%	161	83.61%	188	99.45%
108	1.37%	135	39.89%	162	84.43%	189	99.45%
109	1.91%	136	41.53%	163	86.34%	190	99.45%
110	1.91%	137	43.44%	164	87.16%	191	99.45%
111	3.28%	138	44.81%	165	88.25%	192	99.45%
112	4.10%	139	46.17%	166	89.62%	193	99.45%
113	4.92%	140	47.54%	167	90.16%	194	99.45%
114	5.74%	141	50.27%	168	91.53%	195	99.45%
115	6.28%	142	51.91%	169	92.35%	196	99.73%
116	6.83%	143	53.28%	170	92.90%	197	99.73%
117	8.20%	144	56.01%	171	93.44%	198	99.73%
118	8.74%	145	57.10%	172	94.26%	199	99.73%
119	10.11%	146	58.74%	173	95.36%	200	99.73%
120	10.93%	147	60.93%	174	95.63%	201	99.73%
121	12.30%	148	63.11%	175	95.90%	202	99.73%
122	14.75%	149	64.21%	176	96.72%	203	100.00%
123	16.39%	150	66.12%	177	96.72%		

Replication 4:

# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)
97	.27%	123	21.31%	149	68.31%	175	98.91%
98	.27%	124	22.68%	150	69.95%	176	99.18%
99	.55%	125	25.14%	151	71.58%	177	99.18%
100	.55%	126	26.78%	152	72.95%	178	99.18%
101	1.09%	127	28.69%	153	74.86%	179	99.45%
102	1.09%	128	29.51%	154	77.87%	180	99.45%
103	1.09%	129	31.69%	155	80.33%	181	99.73%
104	1.09%	130	32.24%	156	81.69%	182	99.73%
105	1.37%	131	34.15%	157	83.88%	183	99.73%
106	2.19%	132	36.89%	158	86.07%	184	99.73%
107	2.73%	133	38.80%	159	87.70%	185	99.73%
108	3.01%	134	40.71%	160	88.52%	186	99.73%
109	3.55%	135	44.81%	161	90.16%	187	99.73%
110	4.64%	136	45.63%	162	91.80%	188	99.73%
111	6.56%	137	47.81%	163	92.90%	189	99.73%
112	7.38%	138	49.18%	164	94.81%	190	99.73%
113	8.74%	139	50.00%	165	95.08%	191	99.73%
114	9.84%	140	52.19%	166	95.63%	192	99.73%
115	10.66%	141	53.55%	167	96.45%	193	99.73%
116	13.39%	142	55.19%	168	96.72%	194	99.73%
117	15.03%	143	56.83%	169	97.27%	195	99.73%
118	16.12%	144	60.11%	170	97.27%	196	99.73%
119	16.94%	145	62.02%	171	98.36%	197	99.73%
120	17.49%	146	63.39%	172	98.63%	198	99.73%
121	17.76%	147	65.30%	173	98.63%	199	99.73%
122	19.95%	148	66.94%	174	98.91%	200	100.00%

Replication 5:

# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)
101	.27%	124	11.48%	147	58.74%	170	92.35%
102	.27%	125	13.39%	148	61.20%	171	93.44%
103	.27%	126	14.48%	149	62.30%	172	93.99%
104	.27%	127	16.12%	150	65.30%	173	94.26%
105	.82%	128	18.31%	151	67.21%	174	94.26%
106	.82%	129	19.40%	152	68.85%	175	94.54%
107	1.64%	130	21.86%	153	69.95%	176	95.08%
108	1.91%	131	22.95%	154	72.13%	177	95.90%
109	2.19%	132	23.77%	155	75.14%	178	95.90%
110	2.46%	133	26.23%	156	76.50%	179	96.45%
111	2.73%	134	27.87%	157	78.69%	180	96.99%
112	3.28%	135	31.69%	158	80.33%	181	97.54%
113	3.55%	136	33.33%	159	82.79%	182	97.81%
114	3.83%	137	35.25%	160	83.61%	183	97.81%
115	3.83%	138	38.52%	161	84.97%	184	98.36%
116	4.64%	139	40.16%	162	85.79%	185	98.63%
117	5.46%	140	41.26%	163	87.43%	186	98.91%
118	5.74%	141	44.54%	164	87.98%	187	99.18%
119	6.01%	142	45.36%	165	88.80%	188	99.73%
120	7.38%	143	48.91%	166	90.16%	189	99.73%
121	7.92%	144	50.82%	167	90.44%	190	100.00%
122	9.56%	145	53.83%	168	90.98%		
123	10.38%	146	55.74%	169	91.53%		

Replication 6:

# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)
91	.27%	117	12.02%	143	62.57%	169	94.26%
92	.27%	118	12.84%	144	64.48%	170	94.54%
93	.27%	119	14.21%	145	66.94%	171	95.08%
94	.27%	120	16.94%	146	69.40%	172	95.63%
95	.27%	121	17.49%	147	71.31%	173	96.45%
96	.55%	122	18.31%	148	73.77%	174	96.45%
97	.82%	123	20.22%	149	75.14%	175	96.72%
98	.82%	124	20.77%	150	76.23%	176	96.99%
99	.82%	125	23.77%	151	77.87%	177	97.54%
100	.82%	126	24.59%	152	78.69%	178	97.54%
101	.82%	127	25.41%	153	81.15%	179	97.54%
102	1.09%	128	26.23%	154	82.24%	180	97.54%
103	1.37%	129	28.14%	155	83.06%	181	98.36%
104	1.91%	130	30.60%	156	84.70%	182	98.36%
105	2.19%	131	33.06%	157	84.97%	183	98.63%
106	2.73%	132	35.52%	158	86.07%	184	98.63%
107	3.28%	133	37.70%	159	87.43%	185	98.91%
108	3.83%	134	39.62%	160	87.98%	186	98.91%
109	4.37%	135	42.08%	161	88.52%	187	99.45%
110	5.74%	136	44.81%	162	88.80%	188	99.45%
111	6.56%	137	47.81%	163	89.89%	189	99.45%
112	7.10%	138	50.82%	164	90.44%	190	99.45%
113	7.38%	139	53.55%	165	91.53%	191	99.45%
114	8.20%	140	56.83%	166	92.90%	192	99.73%
115	8.74%	141	58.74%	167	93.17%	193	100.00%
116	10.93%	142	60.11%	168	93.44%		

Replication 7:

# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)
82	.27%	107	6.28%	132	43.72%	157	85.25%
83	.27%	108	6.83%	133	46.45%	158	85.52%
84	.27%	109	7.92%	134	48.09%	159	87.16%
85	.55%	110	9.29%	135	50.82%	160	87.43%
86	.82%	111	10.38%	136	52.46%	161	87.98%
87	.82%	112	10.66%	137	54.37%	162	89.07%
88	.82%	113	11.75%	138	57.65%	163	90.44%
89	.82%	114	13.11%	139	59.56%	164	91.26%
90	1.09%	115	15.30%	140	60.38%	165	92.08%
91	1.09%	116	16.12%	141	64.21%	166	92.35%
92	1.09%	117	17.76%	142	65.30%	167	93.17%
93	1.37%	118	18.58%	143	66.67%	168	94.26%
94	1.37%	119	19.13%	144	68.85%	169	94.81%
95	1.64%	120	19.67%	145	70.77%	170	95.36%
96	1.64%	121	21.04%	146	71.31%	171	95.36%
97	1.64%	122	22.68%	147	73.22%	172	95.63%
98	1.91%	123	24.86%	148	73.77%	173	96.72%
99	2.46%	124	26.50%	149	76.23%	174	96.99%
100	2.73%	125	28.96%	150	77.05%	175	97.54%
101	3.01%	126	31.69%	151	78.42%	176	98.36%
102	3.55%	127	33.33%	152	78.42%	177	99.18%
103	3.55%	128	35.25%	153	79.51%	178	99.73%
104	3.83%	129	37.43%	154	81.15%	179	100.00%
105	4.10%	130	39.07%	155	82.79%		
106	4.37%	131	40.98%	156	83.06%		

Replication 8:

# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)
50	.27%	87	1.09%	124	18.03%	161	85.25%
51	.27%	88	1.09%	125	19.40%	162	86.61%
52	.27%	89	1.09%	126	19.95%	163	88.25%
53	.27%	90	1.09%	127	21.04%	164	88.80%
54	.27%	91	1.09%	128	21.86%	165	89.62%
55	.27%	92	1.09%	129	24.32%	166	90.16%
56	.27%	93	1.09%	130	26.23%	167	90.98%
57	.55%	94	1.09%	131	27.32%	168	91.53%
58	.55%	95	1.09%	132	28.96%	169	92.90%
59	.55%	96	1.09%	133	30.33%	170	93.44%
60	.55%	97	1.09%	134	31.42%	171	93.99%
61	.55%	98	1.09%	135	33.61%	172	94.26%
62	.55%	99	1.09%	136	35.79%	173	94.81%
63	.55%	100	1.09%	137	37.70%	174	95.08%
64	.82%	101	1.37%	138	39.62%	175	96.17%
65	.82%	102	1.64%	139	41.80%	176	96.99%
66	.82%	103	1.91%	140	45.63%	177	97.27%
67	.82%	104	2.19%	141	48.09%	178	97.81%
68	.82%	105	2.19%	142	49.45%	179	98.09%
69	.82%	106	2.73%	143	51.64%	180	98.09%
70	.82%	107	3.01%	144	54.64%	181	98.36%
71	.82%	108	3.01%	145	56.83%	182	98.91%
72	.82%	109	4.64%	146	59.84%	183	98.91%
73	.82%	110	5.74%	147	61.75%	184	99.18%
74	.82%	111	6.28%	148	63.39%	185	99.45%
75	.82%	112	6.83%	149	65.57%	186	99.45%
76	.82%	113	7.38%	150	67.49%	187	99.45%
77	.82%	114	7.65%	151	68.58%	188	99.45%
78	.82%	115	8.20%	152	71.04%	189	99.45%
79	.82%	116	9.29%	153	72.40%	190	99.73%
80	.82%	117	10.66%	154	74.32%	191	99.73%
81	.82%	118	12.02%	155	76.23%	192	99.73%
82	1.09%	119	12.84%	156	78.69%	193	99.73%
83	1.09%	120	14.48%	157	79.23%	194	100.00%
84	1.09%	121	15.30%	158	81.15%		
85	1.09%	122	16.94%	159	83.06%		
86	1.09%	123	17.21%	160	84.43%		

Replication 9:

# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)
99	.27%	121	7.92%	143	45.36%	165	89.89%
100	.27%	122	9.02%	144	47.54%	166	91.53%
101	.82%	123	9.84%	145	50.55%	167	92.35%
102	1.09%	124	11.75%	146	52.73%	168	93.17%
103	1.37%	125	12.84%	147	55.46%	169	94.54%
104	1.37%	126	13.66%	148	57.38%	170	95.36%
105	1.64%	127	15.30%	149	59.29%	171	95.36%
106	1.91%	128	16.39%	150	61.20%	172	96.17%
107	2.46%	129	18.03%	151	65.30%	173	97.27%
108	2.46%	130	19.67%	152	66.67%	174	97.54%
109	2.46%	131	20.49%	153	68.58%	175	97.81%
110	2.73%	132	21.31%	154	69.95%	176	98.36%
111	2.73%	133	21.58%	155	72.40%	177	98.91%
112	2.73%	134	23.77%	156	74.32%	178	98.91%
113	2.73%	135	26.50%	157	76.78%	179	99.18%
114	3.28%	136	28.42%	158	78.14%	180	99.18%
115	3.83%	137	31.69%	159	80.60%	181	99.73%
116	3.83%	138	33.33%	160	83.06%	182	99.73%
117	4.64%	139	36.07%	161	85.52%	183	99.73%
118	4.92%	140	37.70%	162	86.61%	184	99.73%
119	6.01%	141	40.71%	163	87.98%	185	100.00%
120	7.38%	142	43.44%	164	89.89%		

Replication 10:

# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)	# of Pumps	SL (%)
96	.27%	121	13.39%	146	53.28%	171	92.08%
97	.27%	122	13.66%	147	56.28%	172	93.17%
98	.27%	123	15.85%	148	57.65%	173	93.72%
99	.55%	124	18.85%	149	58.74%	174	96.17%
100	.55%	125	19.40%	150	62.30%	175	96.72%
101	.82%	126	19.95%	151	64.21%	176	96.99%
102	.82%	127	20.49%	152	65.85%	177	96.99%
103	1.37%	128	22.40%	153	66.94%	178	97.27%
104	1.91%	129	24.86%	154	67.76%	179	97.81%
105	1.91%	130	25.68%	155	68.85%	180	97.81%
106	2.46%	131	27.32%	156	70.22%	181	98.36%
107	2.46%	132	29.23%	157	70.49%	182	98.36%
108	3.28%	133	31.42%	158	71.86%	183	98.91%
109	3.83%	134	33.33%	159	74.59%	184	98.91%
110	3.83%	135	34.15%	160	77.05%	185	98.91%
111	4.37%	136	36.07%	161	79.51%	186	98.91%
112	4.92%	137	38.25%	162	81.69%	187	98.91%
113	5.46%	138	40.44%	163	83.61%	188	98.91%
114	5.74%	139	42.08%	164	85.79%	189	99.45%
115	6.56%	140	43.17%	165	86.89%	190	99.73%
116	7.38%	141	45.63%	166	88.25%	191	99.73%
117	8.74%	142	47.54%	167	89.07%	192	100.00%
118	9.84%	143	48.91%	168	90.16%		
119	11.48%	144	50.82%	169	90.44%		
120	12.57%	145	51.37%	170	91.80%		

Appendix K

Average Time (in Hours) Spent to Retrieve Pumps per Day, by Department – RFID System

CCU:

Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours
21	0.03	82	0.23	143	0.32	204	0.30	265	0.57	326	0.33
22	0.22	83	0.28	144	0.08	205	0.10	266	0.38	327	0.23
23	0.52	84	0.45	145	0.25	206	0.32	267	0.42	328	0.20
24	0.22	85	0.20	146	0.33	207	0.13	268	0.40	329	0.38
25	0.48	86	0.40	147	0.37	208	0.28	269	0.42	330	0.03
26	0.25	87	0.20	148	0.38	209	0.22	270	0.22	331	0.62
27	0.33	88	0.57	149	0.37	210	0.32	271	0.28	332	0.28
28	0.45	89	0.33	150	0.08	211	0.28	272	0.23	333	0.37
29	0.15	90	0.33	151	0.60	212	0.28	273	0.35	334	0.07
30	0.33	91	0.18	152	0.22	213	0.43	274	0.13	335	0.45
31	0.17	92	0.27	153	0.38	214	0.45	275	0.63	336	0.33
32	0.22	93	0.30	154	0.25	215	0.15	276	0.15	337	0.40
33	0.15	94	0.23	155	0.13	216	0.25	277	0.60	338	0.17
34	0.13	95	0.37	156	0.10	217	0.17	278	0.17	339	0.30
35	0.57	96	0.37	157	0.40	218	0.42	279	0.38	340	0.33
36	0.35	97	0.37	158	0.27	219	0.20	280	0.18	341	0.37
37	0.15	98	0.07	159	0.05	220	0.28	281	0.18	342	0.20
38	0.52	99	0.15	160	0.32	221	0.30	282	0.28	343	0.35
39	0.27	100	0.27	161	0.70	222	0.70	283	0.18	344	0.12
40	0.45	101	0.40	162	0.15	223	0.40	284	0.28	345	0.23
41	0.67	102	0.13	163	0.12	224	0.42	285	0.15	346	0.42
42	0.23	103	0.37	164	0.18	225	0.18	286	0.33	347	0.15
43	0.37	104	0.08	165	0.32	226	0.28	287	0.60	348	0.35
44	0.32	105	0.48	166	0.43	227	0.20	288	0.03	349	0.32
45	0.22	106	0.35	167	0.22	228	0.13	289	0.13	350	0.22
46	0.05	107	0.53	168	0.18	229	0.35	290	0.40	351	0.40
47	0.80	108	0.62	169	0.28	230	0.27	291	0.23	352	0.38
48	0.07	109	0.38	170	0.20	231	0.43	292	0.33	353	0.08
49	0.37	110	0.08	171	0.18	232	0.07	293	0.40	354	0.53
50	0.38	111	0.23	172	0.47	233	0.38	294	0.30	355	0.23
51	0.17	112	0.12	173	0.23	234	0.22	295	0.18	356	0.30
52	0.13	113	0.42	174	0.15	235	0.48	296	0.15	357	0.20
53	0.40	114	0.23	175	0.18	236	0.17	297	0.18	358	0.27
54	0.43	115	0.45	176	0.32	237	0.45	298	0.47	359	0.18
55	0.75	116	0.48	177	0.27	238	0.28	299	0.42	360	0.30
56	0.22	117	0.18	178	0.63	239	0.17	300	0.28	361	0.23
57	0.13	118	0.40	179	0.42	240	0.33	301	0.40	362	0.33
58	0.20	119	0.22	180	0.10	241	0.72	302	0.20	363	0.20
59	0.37	120	0.28	181	0.35	242	0.23	303	0.52	364	0.13
60	0.18	121	0.35	182	0.33	243	0.08	304	0.27	365	0.42
61	0.65	122	0.38	183	0.53	244	0.33	305	0.15	366	0.28
62	0.18	123	0.20	184	0.32	245	0.22	306	0.13	367	0.32
63	0.17	124	0.10	185	0.37	246	0.20	307	0.27	368	0.27
64	0.32	125	0.25	186	0.33	247	0.25	308	0.43	369	0.58
65	0.17	126	0.33	187	0.47	248	0.08	309	0.13	370	0.52
66	0.53	127	0.33	188	0.50	249	0.72	310	0.45	371	0.17
67	0.17	128	0.33	189	0.38	250	0.12	311	0.37	372	0.53
68	0.47	129	0.48	190	0.12	251	0.05	312	0.50	373	0.17
69	0.23	130	0.43	191	0.28	252	0.25	313	0.33	374	0.40
70	0.33	131	0.13	192	0.25	253	0.12	314	0.28	375	0.57
71	0.15	132	0.28	193	0.25	254	0.40	315	0.25	376	0.23
72	0.23	133	0.07	194	0.40	255	0.27	316	0.47	377	0.35
73	0.48	134	0.58	195	0.32	256	0.23	317	0.22	378	0.27
74	0.23	135	0.35	196	0.13	257	0.08	318	0.10	379	0.35
75	0.65	136	0.42	197	0.33	258	0.23	319	0.28	380	0.35
76	0.15	137	0.50	198	0.33	259	0.40	320	0.28	381	0.13
77	0.17	138	0.12	199	0.40	260	0.25	321	0.42	382	0.48
78	0.22	139	0.38	200	0.35	261	0.43	322	0.20	383	0.10
79	0.17	140	0.15	201	0.32	262	0.27	323	0.25	384	0.17
80	0.52	141	0.40	202	0.32	263	0.25	324	0.18	385	0.08
81	0.35	142	0.63	203	0.37	264	0.30	325	0.58		

General Surgery:

Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours
21	0.93	82	0.43	143	0.43	204	0.27	265	0.65	326	1.15
22	0.67	83	0.75	144	0.42	205	0.38	266	0.87	327	0.38
23	0.10	84	0.07	145	0.65	206	0.47	267	0.62	328	0.32
24	0.97	85	0.30	146	0.55	207	0.45	268	0.68	329	0.87
25	0.60	86	0.30	147	0.32	208	1.20	269	0.58	330	0.28
26	0.60	87	1.35	148	0.37	209	0.25	270	0.08	331	0.25
27	0.20	88	0.35	149	0.45	210	0.42	271	0.45	332	1.20
28	0.37	89	1.00	150	0.57	211	0.63	272	0.63	333	0.47
29	0.40	90	0.78	151	1.00	212	0.28	273	0.67	334	0.62
30	0.73	91	0.60	152	0.37	213	0.57	274	0.28	335	0.25
31	0.52	92	0.57	153	0.72	214	0.37	275	0.75	336	0.37
32	0.75	93	0.45	154	0.55	215	0.12	276	0.18	337	0.33
33	0.60	94	0.30	155	0.35	216	0.42	277	0.48	338	0.42
34	0.57	95	0.25	156	0.53	217	0.85	278	0.53	339	0.73
35	0.23	96	1.20	157	0.87	218	0.78	279	0.57	340	0.27
36	0.48	97	0.28	158	0.50	219	1.00	280	0.90	341	0.50
37	0.88	98	1.10	159	0.58	220	0.27	281	0.52	342	0.63
38	0.50	99	0.47	160	0.45	221	0.65	282	0.35	343	0.35
39	0.43	100	0.43	161	0.35	222	0.38	283	0.28	344	0.60
40	0.37	101	0.30	162	0.48	223	0.60	284	1.35	345	0.62
41	0.78	102	0.85	163	0.67	224	0.57	285	0.83	346	0.67
42	0.38	103	0.48	164	0.47	225	0.33	286	0.12	347	0.37
43	0.63	104	0.52	165	0.67	226	0.55	287	0.58	348	0.47
44	1.03	105	0.65	166	0.03	227	0.62	288	0.85	349	0.50
45	0.63	106	0.45	167	0.28	228	0.32	289	0.10	350	0.23
46	0.35	107	0.67	168	1.08	229	0.07	290	0.17	351	0.78
47	0.93	108	0.43	169	0.42	230	1.08	291	0.60	352	0.47
48	0.30	109	0.38	170	0.58	231	0.27	292	0.35	353	0.15
49	0.35	110	0.05	171	0.47	232	0.18	293	0.70	354	0.57
50	0.25	111	0.53	172	0.72	233	0.53	294	0.80	355	1.03
51	0.30	112	0.58	173	0.48	234	0.35	295	0.35	356	0.13
52	0.90	113	0.55	174	0.35	235	0.65	296	0.17	357	0.28
53	0.10	114	0.38	175	0.35	236	0.32	297	0.30	358	0.35
54	0.98	115	0.77	176	0.32	237	0.32	298	0.38	359	0.48
55	0.97	116	0.55	177	0.88	238	0.50	299	0.72	360	0.33
56	0.48	117	0.73	178	0.48	239	0.68	300	0.42	361	0.93
57	0.00	118	0.57	179	0.32	240	0.90	301	0.20	362	0.77
58	1.12	119	0.85	180	0.92	241	0.50	302	0.93	363	0.88
59	0.68	120	0.27	181	0.62	242	0.47	303	0.45	364	0.62
60	0.40	121	0.23	182	0.68	243	0.48	304	0.37	365	0.23
61	0.72	122	0.65	183	0.50	244	0.40	305	0.58	366	0.90
62	0.43	123	0.83	184	1.17	245	0.73	306	0.85	367	0.57
63	0.82	124	0.65	185	0.40	246	0.08	307	0.78	368	0.67
64	0.25	125	0.28	186	0.15	247	0.80	308	0.15	369	0.62
65	0.83	126	0.98	187	0.23	248	0.80	309	0.57	370	0.57
66	0.62	127	0.37	188	0.68	249	0.32	310	0.20	371	0.37
67	0.42	128	0.60	189	0.67	250	0.53	311	0.52	372	0.63
68	0.13	129	0.43	190	0.48	251	0.42	312	0.67	373	0.30
69	0.78	130	0.72	191	0.37	252	0.58	313	0.63	374	0.37
70	0.40	131	0.33	192	0.50	253	0.52	314	0.33	375	0.97
71	0.63	132	0.58	193	0.50	254	1.10	315	0.38	376	0.32
72	0.25	133	0.93	194	0.32	255	0.22	316	0.58	377	1.02
73	0.75	134	0.38	195	0.70	256	0.58	317	0.47	378	0.43
74	0.77	135	0.23	196	0.45	257	0.30	318	0.80	379	0.47
75	0.33	136	0.80	197	0.72	258	0.70	319	0.32	380	0.37
76	0.23	137	0.07	198	0.57	259	0.57	320	0.28	381	0.27
77	0.53	138	0.63	199	0.45	260	0.28	321	0.73	382	0.53
78	0.38	139	0.33	200	0.53	261	0.20	322	0.55	383	0.27
79	0.73	140	0.63	201	1.02	262	0.68	323	0.70	384	0.20
80	0.18	141	0.75	202	0.30	263	0.00	324	0.65	385	0.82
81	0.63	142	0.92	203	0.68	264	0.43	325	0.33		

ICU:

Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours
21	0.52	82	0.30	143	0.43	204	0.53	265	0.45	326	0.58
22	0.93	83	0.17	144	0.30	205	0.43	266	0.75	327	0.62
23	0.77	84	1.05	145	1.25	206	0.62	267	0.60	328	0.35
24	0.48	85	0.25	146	0.67	207	1.23	268	0.82	329	0.50
25	0.53	86	0.98	147	0.32	208	0.47	269	0.35	330	0.43
26	0.75	87	0.58	148	0.57	209	0.73	270	0.47	331	1.22
27	0.22	88	0.40	149	0.85	210	0.53	271	0.95	332	1.28
28	0.92	89	0.52	150	0.33	211	1.12	272	0.78	333	0.40
29	0.50	90	0.68	151	0.72	212	0.43	273	1.03	334	0.68
30	0.97	91	0.62	152	0.57	213	0.85	274	0.22	335	0.32
31	0.47	92	0.43	153	0.55	214	0.80	275	0.77	336	1.02
32	0.28	93	0.78	154	0.37	215	0.27	276	1.18	337	0.58
33	0.18	94	0.75	155	0.23	216	0.77	277	0.57	338	1.28
34	1.30	95	0.52	156	1.27	217	0.52	278	0.55	339	0.65
35	0.88	96	0.55	157	0.20	218	0.17	279	0.55	340	0.57
36	0.78	97	0.70	158	0.25	219	1.05	280	0.67	341	0.63
37	0.35	98	0.42	159	0.53	220	0.53	281	0.35	342	0.82
38	0.60	99	0.27	160	0.57	221	0.70	282	0.72	343	0.63
39	0.88	100	0.40	161	0.25	222	0.75	283	0.75	344	0.52
40	0.97	101	0.38	162	0.85	223	0.72	284	0.72	345	0.28
41	0.53	102	0.60	163	0.42	224	0.42	285	0.22	346	0.52
42	0.52	103	0.70	164	0.68	225	0.60	286	0.33	347	0.47
43	0.35	104	0.33	165	0.58	226	0.20	287	0.80	348	0.40
44	0.45	105	0.40	166	0.67	227	0.30	288	0.33	349	0.18
45	0.75	106	0.70	167	0.57	228	0.68	289	0.73	350	1.05
46	1.03	107	0.48	168	0.25	229	0.67	290	0.32	351	0.80
47	0.43	108	1.23	169	0.22	230	0.35	291	1.17	352	0.48
48	0.82	109	0.78	170	0.68	231	0.83	292	0.27	353	0.42
49	0.57	110	0.27	171	0.80	232	0.47	293	0.58	354	0.92
50	0.35	111	0.68	172	1.13	233	0.80	294	0.32	355	0.50
51	0.22	112	0.72	173	0.28	234	0.35	295	0.58	356	0.73
52	0.55	113	0.25	174	0.50	235	0.30	296	0.20	357	0.60
53	0.88	114	0.43	175	0.53	236	0.42	297	0.90	358	0.10
54	0.47	115	1.25	176	0.73	237	0.27	298	1.25	359	0.98
55	1.02	116	1.02	177	0.23	238	0.50	299	0.48	360	0.93
56	0.47	117	0.42	178	0.47	239	0.82	300	0.78	361	0.12
57	0.62	118	0.65	179	0.72	240	1.58	301	0.65	362	0.75
58	0.28	119	0.52	180	0.65	241	0.57	302	0.60	363	0.63
59	0.42	120	0.47	181	0.55	242	0.45	303	1.02	364	0.52
60	0.33	121	0.42	182	1.25	243	0.38	304	0.48	365	0.55
61	0.92	122	0.33	183	0.50	244	0.77	305	0.50	366	0.58
62	0.93	123	1.32	184	0.88	245	0.75	306	0.48	367	1.20
63	0.27	124	0.33	185	0.40	246	0.88	307	0.18	368	0.48
64	0.73	125	0.98	186	0.25	247	0.60	308	0.25	369	0.18
65	0.55	126	0.37	187	0.83	248	1.17	309	0.30	370	0.10
66	0.52	127	0.57	188	0.97	249	0.53	310	1.20	371	0.60
67	0.53	128	0.67	189	0.88	250	0.05	311	0.20	372	0.45
68	0.80	129	0.67	190	1.03	251	0.95	312	0.28	373	1.35
69	0.50	130	0.57	191	0.62	252	0.92	313	0.78	374	0.70
70	0.60	131	0.80	192	0.08	253	0.68	314	1.67	375	0.57
71	0.47	132	0.85	193	0.42	254	0.43	315	0.18	376	0.22
72	0.77	133	0.87	194	0.75	255	0.75	316	1.33	377	0.98
73	0.58	134	0.88	195	0.37	256	1.10	317	0.07	378	0.65
74	0.50	135	0.43	196	0.78	257	0.38	318	0.92	379	0.85
75	0.67	136	0.55	197	0.65	258	0.65	319	0.43	380	0.88
76	0.62	137	0.15	198	0.85	259	0.23	320	0.45	381	0.27
77	0.10	138	0.87	199	0.48	260	0.95	321	1.03	382	0.82
78	0.85	139	0.48	200	0.23	261	0.22	322	0.77	383	0.42
79	0.22	140	0.98	201	0.50	262	0.63	323	0.43	384	0.38
80	0.95	141	0.83	202	0.57	263	1.28	324	0.22	385	0.43
81	1.05	142	1.10	203	0.57	264	0.52	325	0.35		

Medical Program:

Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours
21	0.00	82	0.15	143	0.53	204	0.10	265	0.18	326	0.48
22	0.38	83	0.32	144	0.03	205	0.28	266	0.28	327	0.10
23	0.25	84	0.27	145	0.20	206	0.43	267	0.18	328	0.22
24	0.13	85	0.47	146	0.38	207	0.28	268	0.10	329	0.12
25	0.42	86	0.18	147	0.25	208	0.10	269	0.40	330	0.33
26	0.23	87	0.20	148	0.25	209	0.33	270	0.00	331	0.30
27	0.22	88	0.17	149	0.15	210	0.20	271	0.38	332	0.22
28	0.17	89	0.32	150	0.45	211	0.35	272	0.18	333	0.18
29	0.42	90	0.17	151	0.43	212	0.35	273	0.08	334	0.38
30	0.28	91	0.15	152	0.17	213	0.35	274	0.52	335	0.15
31	0.60	92	0.37	153	0.32	214	0.13	275	0.17	336	0.05
32	0.22	93	0.35	154	0.15	215	0.40	276	0.23	337	0.37
33	0.18	94	0.15	155	0.42	216	0.30	277	0.45	338	0.12
34	0.18	95	0.13	156	0.10	217	0.30	278	0.20	339	0.15
35	0.32	96	0.15	157	0.05	218	0.37	279	0.18	340	0.57
36	0.20	97	0.37	158	0.32	219	0.30	280	0.22	341	0.32
37	0.27	98	0.40	159	0.27	220	0.10	281	0.33	342	0.40
38	0.18	99	0.22	160	0.33	221	0.27	282	0.42	343	0.03
39	0.25	100	0.50	161	0.30	222	0.33	283	0.20	344	0.15
40	0.38	101	0.10	162	0.20	223	0.25	284	0.33	345	0.40
41	0.23	102	0.13	163	0.22	224	0.17	285	0.13	346	0.23
42	0.23	103	0.37	164	0.23	225	0.35	286	0.22	347	0.25
43	0.48	104	0.25	165	0.23	226	0.17	287	0.27	348	0.33
44	0.27	105	0.17	166	0.13	227	0.13	288	0.27	349	0.08
45	0.27	106	0.37	167	0.13	228	0.43	289	0.28	350	0.30
46	0.17	107	0.30	168	0.20	229	0.18	290	0.37	351	0.25
47	0.20	108	0.07	169	0.70	230	0.18	291	0.13	352	0.28
48	0.20	109	0.37	170	0.23	231	0.17	292	0.27	353	0.18
49	0.27	110	0.08	171	0.18	232	0.43	293	0.43	354	0.43
50	0.25	111	0.38	172	0.30	233	0.18	294	0.27	355	0.40
51	0.32	112	0.23	173	0.38	234	0.30	295	0.28	356	0.17
52	0.23	113	0.18	174	0.23	235	0.25	296	0.18	357	0.48
53	0.37	114	0.30	175	0.32	236	0.43	297	0.25	358	0.32
54	0.32	115	0.23	176	0.10	237	0.27	298	0.75	359	0.05
55	0.18	116	0.23	177	0.18	238	0.32	299	0.33	360	0.25
56	0.33	117	0.40	178	0.07	239	0.13	300	0.28	361	0.27
57	0.35	118	0.30	179	0.37	240	0.12	301	0.20	362	0.18
58	0.27	119	0.43	180	0.20	241	0.22	302	0.15	363	0.20
59	0.25	120	0.15	181	0.57	242	0.53	303	0.22	364	0.22
60	0.23	121	0.27	182	0.25	243	0.03	304	0.08	365	0.10
61	0.13	122	0.37	183	0.23	244	0.20	305	0.32	366	0.18
62	0.35	123	0.27	184	0.12	245	0.47	306	0.50	367	0.55
63	0.02	124	0.38	185	0.60	246	0.27	307	0.05	368	0.40
64	0.52	125	0.07	186	0.20	247	0.25	308	0.22	369	0.13
65	0.20	126	0.32	187	0.35	248	0.47	309	0.32	370	0.35
66	0.07	127	0.30	188	0.42	249	0.18	310	0.17	371	0.13
67	0.38	128	0.27	189	0.08	250	0.55	311	0.33	372	0.23
68	0.28	129	0.48	190	0.23	251	0.08	312	0.08	373	0.15
69	0.25	130	0.25	191	0.20	252	0.08	313	0.40	374	0.17
70	0.18	131	0.10	192	0.15	253	0.42	314	0.23	375	0.28
71	0.18	132	0.22	193	0.17	254	0.10	315	0.22	376	0.30
72	0.45	133	0.47	194	0.43	255	0.48	316	0.08	377	0.20
73	0.07	134	0.33	195	0.23	256	0.43	317	0.30	378	0.35
74	0.37	135	0.18	196	0.42	257	0.18	318	0.28	379	0.25
75	0.32	136	0.17	197	0.07	258	0.20	319	0.18	380	0.12
76	0.20	137	0.15	198	0.25	259	0.27	320	0.73	381	0.12
77	0.25	138	0.37	199	0.22	260	0.30	321	0.18	382	0.47
78	0.10	139	0.48	200	0.25	261	0.07	322	0.52	383	0.05
79	0.33	140	0.03	201	0.30	262	0.30	323	0.55	384	0.33
80	0.18	141	0.48	202	0.35	263	0.30	324	0.48	385	0.12
81	0.27	142	0.48	203	0.13	264	0.30	325	0.08		

Oncology:

Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours
21	0.45	82	0.17	143	0.22	204	0.38	265	0.17	326	0.25
22	0.12	83	0.32	144	0.28	205	0.15	266	0.22	327	0.03
23	0.25	84	0.28	145	0.00	206	0.27	267	0.18	328	0.22
24	0.25	85	0.18	146	0.13	207	0.08	268	0.10	329	0.17
25	0.42	86	0.15	147	0.12	208	0.32	269	0.33	330	0.13
26	0.05	87	0.23	148	0.08	209	0.27	270	0.42	331	0.12
27	0.35	88	0.17	149	0.38	210	0.18	271	0.28	332	0.22
28	0.28	89	0.07	150	0.10	211	0.08	272	0.20	333	0.23
29	0.25	90	0.07	151	0.17	212	0.23	273	0.18	334	0.20
30	0.10	91	0.38	152	0.38	213	0.10	274	0.28	335	0.18
31	0.13	92	0.10	153	0.08	214	0.17	275	0.23	336	0.25
32	0.22	93	0.08	154	0.13	215	0.20	276	0.08	337	0.27
33	0.47	94	0.12	155	0.17	216	0.18	277	0.33	338	0.10
34	0.32	95	0.12	156	0.15	217	0.32	278	0.18	339	0.22
35	0.03	96	0.28	157	0.05	218	0.00	279	0.18	340	0.07
36	0.10	97	0.25	158	0.23	219	0.28	280	0.12	341	0.38
37	0.05	98	0.18	159	0.27	220	0.18	281	0.10	342	0.08
38	0.07	99	0.12	160	0.10	221	0.15	282	0.05	343	0.23
39	0.48	100	0.18	161	0.12	222	0.13	283	0.40	344	0.07
40	0.17	101	0.37	162	0.20	223	0.40	284	0.18	345	0.22
41	0.17	102	0.18	163	0.08	224	0.38	285	0.23	346	0.12
42	0.17	103	0.08	164	0.37	225	0.12	286	0.27	347	0.12
43	0.27	104	0.22	165	0.23	226	0.25	287	0.15	348	0.20
44	0.30	105	0.30	166	0.33	227	0.07	288	0.23	349	0.30
45	0.23	106	0.18	167	0.20	228	0.15	289	0.17	350	0.23
46	0.43	107	0.13	168	0.17	229	0.18	290	0.22	351	0.15
47	0.18	108	0.32	169	0.08	230	0.30	291	0.12	352	0.27
48	0.23	109	0.07	170	0.17	231	0.37	292	0.18	353	0.05
49	0.18	110	0.18	171	0.27	232	0.17	293	0.08	354	0.17
50	0.13	111	0.07	172	0.25	233	0.10	294	0.42	355	0.15
51	0.27	112	0.18	173	0.18	234	0.27	295	0.12	356	0.22
52	0.10	113	0.12	174	0.20	235	0.10	296	0.42	357	0.13
53	0.10	114	0.10	175	0.30	236	0.47	297	0.13	358	0.18
54	0.23	115	0.42	176	0.32	237	0.15	298	0.07	359	0.27
55	0.32	116	0.17	177	0.03	238	0.07	299	0.20	360	0.18
56	0.25	117	0.15	178	0.13	239	0.08	300	0.18	361	0.28
57	0.07	118	0.03	179	0.13	240	0.08	301	0.15	362	0.15
58	0.13	119	0.22	180	0.25	241	0.32	302	0.08	363	0.10
59	0.30	120	0.18	181	0.17	242	0.07	303	0.18	364	0.28
60	0.15	121	0.18	182	0.02	243	0.05	304	0.22	365	0.22
61	0.18	122	0.27	183	0.32	244	0.08	305	0.33	366	0.07
62	0.15	123	0.70	184	0.12	245	0.17	306	0.22	367	0.28
63	0.13	124	0.12	185	0.17	246	0.22	307	0.20	368	0.27
64	0.03	125	0.07	186	0.18	247	0.12	308	0.17	369	0.08
65	0.40	126	0.17	187	0.22	248	0.15	309	0.08	370	0.35
66	0.07	127	0.22	188	0.08	249	0.23	310	0.15	371	0.22
67	0.23	128	0.10	189	0.22	250	0.07	311	0.23	372	0.17
68	0.13	129	0.18	190	0.20	251	0.15	312	0.18	373	0.12
69	0.13	130	0.18	191	0.13	252	0.30	313	0.27	374	0.18
70	0.23	131	0.22	192	0.13	253	0.30	314	0.18	375	0.27
71	0.08	132	0.02	193	0.20	254	0.25	315	0.08	376	0.08
72	0.17	133	0.30	194	0.17	255	0.28	316	0.35	377	0.15
73	0.23	134	0.30	195	0.17	256	0.10	317	0.10	378	0.30
74	0.18	135	0.18	196	0.22	257	0.05	318	0.27	379	0.22
75	0.17	136	0.17	197	0.23	258	0.03	319	0.27	380	0.15
76	0.15	137	0.33	198	0.05	259	0.25	320	0.18	381	0.22
77	0.13	138	0.15	199	0.30	260	0.08	321	0.18	382	0.33
78	0.35	139	0.38	200	0.10	261	0.13	322	0.33	383	0.17
79	0.08	140	0.17	201	0.18	262	0.25	323	0.02	384	0.07
80	0.10	141	0.20	202	0.12	263	0.33	324	0.52	385	0.08
81	0.23	142	0.40	203	0.12	264	0.13	325	0.22		

Paediatrics:

Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours
21	0.23	82	0.18	143	0.25	204	0.27	265	0.03	326	0.17
22	0.15	83	0.57	144	0.85	205	0.47	266	0.28	327	0.08
23	0.23	84	0.47	145	0.17	206	0.32	267	0.47	328	0.23
24	0.52	85	0.13	146	0.17	207	0.12	268	0.32	329	0.28
25	0.73	86	0.22	147	0.15	208	0.18	269	0.40	330	0.38
26	0.45	87	0.18	148	0.15	209	0.20	270	0.33	331	0.23
27	0.37	88	0.32	149	0.32	210	0.18	271	0.28	332	0.32
28	0.23	89	0.48	150	0.33	211	0.08	272	0.13	333	0.20
29	0.27	90	0.25	151	0.23	212	0.23	273	0.32	334	0.40
30	0.17	91	0.17	152	0.22	213	0.40	274	0.38	335	0.17
31	0.13	92	0.37	153	0.55	214	0.30	275	0.27	336	0.63
32	0.37	93	0.40	154	0.18	215	0.13	276	0.10	337	0.30
33	0.23	94	0.22	155	0.10	216	0.37	277	0.45	338	0.13
34	0.47	95	0.37	156	0.27	217	0.40	278	0.07	339	0.23
35	0.17	96	0.10	157	0.22	218	0.03	279	0.15	340	0.30
36	0.30	97	0.45	158	0.37	219	0.23	280	0.23	341	0.45
37	0.10	98	0.05	159	0.22	220	0.17	281	0.27	342	0.35
38	0.50	99	0.47	160	0.40	221	0.37	282	0.20	343	0.13
39	0.38	100	0.33	161	0.17	222	0.33	283	0.23	344	0.25
40	0.32	101	0.18	162	0.47	223	0.33	284	0.40	345	0.53
41	0.38	102	0.27	163	0.08	224	0.25	285	0.23	346	0.25
42	0.23	103	0.17	164	0.22	225	0.37	286	0.40	347	0.23
43	0.28	104	0.08	165	0.35	226	0.32	287	0.43	348	0.28
44	0.43	105	0.32	166	0.33	227	0.30	288	0.20	349	0.22
45	0.12	106	0.50	167	0.13	228	0.05	289	0.37	350	0.47
46	0.23	107	0.22	168	0.17	229	0.35	290	0.42	351	0.17
47	0.27	108	0.20	169	0.27	230	0.32	291	0.22	352	0.62
48	0.07	109	0.25	170	0.27	231	0.18	292	0.15	353	0.05
49	0.25	110	0.12	171	0.65	232	0.42	293	0.22	354	0.20
50	0.35	111	0.58	172	0.20	233	0.28	294	0.20	355	0.17
51	0.30	112	0.25	173	0.13	234	0.15	295	0.45	356	0.10
52	0.22	113	0.28	174	0.68	235	0.33	296	0.43	357	0.27
53	0.03	114	0.12	175	0.40	236	0.13	297	0.23	358	0.33
54	0.33	115	0.48	176	0.43	237	0.40	298	0.27	359	0.12
55	0.57	116	0.25	177	0.08	238	0.47	299	0.10	360	0.37
56	0.23	117	0.38	178	0.25	239	0.17	300	0.17	361	0.33
57	0.27	118	0.42	179	0.22	240	0.20	301	0.33	362	0.30
58	0.13	119	0.27	180	0.33	241	0.08	302	0.20	363	0.07
59	0.30	120	0.35	181	0.25	242	0.30	303	0.65	364	0.17
60	0.53	121	0.23	182	0.10	243	0.33	304	0.10	365	0.73
61	0.40	122	0.18	183	0.53	244	0.23	305	0.38	366	0.20
62	0.10	123	0.23	184	0.35	245	0.17	306	0.28	367	0.37
63	0.07	124	0.28	185	0.33	246	0.57	307	0.07	368	0.72
64	0.27	125	0.17	186	0.08	247	0.10	308	0.25	369	0.12
65	0.70	126	0.58	187	0.52	248	0.32	309	0.28	370	0.03
66	0.37	127	0.28	188	0.40	249	0.18	310	0.45	371	0.15
67	0.20	128	0.23	189	0.15	250	0.13	311	0.32	372	0.30
68	0.32	129	0.35	190	0.28	251	0.48	312	0.23	373	0.32
69	0.42	130	0.32	191	0.52	252	0.52	313	0.12	374	0.37
70	0.18	131	0.38	192	0.47	253	0.13	314	0.28	375	0.32
71	0.38	132	0.13	193	0.18	254	0.35	315	0.20	376	0.32
72	0.32	133	0.13	194	0.23	255	0.22	316	0.28	377	0.08
73	0.28	134	0.15	195	0.13	256	0.03	317	0.20	378	0.33
74	0.38	135	0.25	196	0.28	257	0.32	318	0.58	379	0.97
75	0.15	136	0.33	197	0.22	258	0.15	319	0.13	380	0.20
76	0.27	137	0.42	198	0.15	259	0.65	320	0.15	381	0.43
77	0.28	138	0.25	199	0.40	260	0.18	321	0.20	382	0.35
78	0.15	139	0.33	200	0.35	261	0.47	322	0.27	383	0.20
79	0.18	140	0.33	201	0.20	262	0.13	323	0.25	384	0.22
80	0.15	141	0.25	202	0.48	263	0.02	324	0.08	385	0.15
81	0.48	142	0.30	203	0.12	264	0.63	325	0.48		

Emergency:

Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours	Day	Hours
21	2.13	82	1.97	143	2.10	204	2.27	265	2.05	326	1.53
22	1.92	83	1.90	144	1.95	205	2.22	266	2.03	327	2.02
23	1.95	84	2.32	145	2.40	206	2.17	267	2.05	328	1.87
24	2.13	85	1.78	146	2.03	207	2.22	268	2.30	329	2.17
25	1.75	86	2.12	147	2.18	208	1.98	269	2.08	330	2.23
26	2.27	87	2.02	148	2.35	209	1.80	270	2.32	331	2.40
27	2.10	88	2.22	149	2.15	210	2.07	271	1.83	332	1.87
28	1.98	89	2.08	150	1.98	211	2.00	272	1.92	333	2.08
29	2.30	90	2.05	151	1.92	212	2.13	273	2.57	334	1.92
30	2.53	91	2.23	152	2.22	213	1.85	274	2.10	335	2.00
31	2.48	92	2.53	153	1.82	214	2.12	275	2.02	336	2.32
32	2.03	93	1.93	154	2.10	215	2.03	276	2.23	337	1.90
33	2.23	94	1.88	155	1.92	216	1.93	277	1.85	338	2.08
34	2.13	95	1.67	156	1.90	217	1.72	278	2.43	339	2.35
35	1.98	96	2.05	157	2.38	218	2.28	279	2.22	340	1.87
36	1.92	97	2.42	158	2.18	219	1.68	280	2.37	341	1.90
37	2.12	98	2.05	159	2.33	220	2.32	281	1.82	342	1.95
38	2.28	99	2.03	160	2.13	221	2.18	282	2.03	343	2.25
39	2.15	100	1.82	161	2.02	222	2.05	283	2.75	344	2.15
40	2.10	101	2.32	162	1.80	223	2.37	284	1.82	345	1.82
41	2.05	102	2.22	163	2.15	224	2.13	285	1.78	346	2.33
42	2.25	103	1.72	164	2.27	225	2.48	286	2.02	347	2.22
43	2.15	104	2.07	165	1.95	226	2.25	287	1.87	348	1.77
44	1.95	105	2.45	166	1.80	227	2.35	288	1.93	349	2.30
45	2.22	106	2.05	167	2.12	228	2.02	289	2.02	350	2.13
46	2.65	107	1.98	168	2.07	229	2.20	290	2.08	351	2.25
47	2.02	108	2.00	169	2.02	230	1.85	291	2.12	352	2.10
48	2.32	109	1.83	170	2.10	231	2.07	292	2.12	353	2.43
49	1.85	110	2.22	171	2.53	232	1.85	293	2.07	354	2.23
50	2.27	111	1.87	172	2.23	233	2.12	294	2.15	355	1.87
51	2.05	112	1.82	173	2.27	234	1.90	295	1.93	356	2.20
52	2.27	113	1.90	174	1.92	235	2.10	296	2.13	357	1.92
53	2.32	114	2.42	175	1.80	236	2.42	297	2.48	358	1.88
54	2.23	115	2.02	176	2.00	237	2.17	298	2.23	359	2.08
55	1.93	116	1.92	177	2.03	238	2.18	299	2.18	360	1.98
56	1.87	117	2.27	178	2.23	239	1.92	300	2.17	361	2.00
57	1.93	118	2.12	179	2.08	240	2.05	301	2.35	362	1.88
58	2.27	119	2.18	180	2.03	241	2.20	302	2.52	363	1.77
59	2.10	120	2.07	181	1.87	242	1.90	303	1.83	364	2.15
60	2.22	121	2.00	182	2.42	243	2.12	304	2.30	365	2.03
61	2.10	122	2.20	183	2.17	244	2.05	305	2.13	366	2.20
62	1.80	123	1.80	184	2.42	245	1.75	306	1.52	367	2.22
63	2.08	124	1.78	185	2.05	246	2.07	307	1.95	368	1.70
64	2.17	125	2.52	186	2.57	247	2.17	308	2.42	369	1.98
65	1.85	126	2.22	187	2.20	248	2.02	309	2.07	370	2.27
66	2.10	127	2.38	188	1.95	249	2.13	310	2.38	371	1.88
67	2.23	128	2.32	189	2.13	250	1.97	311	1.87	372	2.07
68	1.77	129	1.85	190	2.05	251	2.13	312	2.13	373	1.90
69	2.13	130	1.83	191	1.98	252	2.22	313	2.00	374	2.42
70	2.37	131	2.10	192	1.95	253	2.05	314	2.30	375	2.05
71	2.32	132	2.32	193	2.27	254	2.22	315	2.12	376	2.25
72	2.20	133	2.27	194	2.43	255	1.80	316	2.00	377	2.40
73	2.32	134	2.15	195	2.17	256	2.18	317	2.18	378	2.13
74	2.38	135	2.12	196	2.00	257	1.93	318	2.00	379	2.07
75	2.07	136	2.23	197	2.18	258	2.33	319	2.43	380	2.10
76	2.00	137	2.22	198	2.35	259	2.02	320	2.03	381	2.45
77	1.87	138	2.15	199	2.05	260	1.93	321	2.18	382	2.07
78	2.25	139	1.92	200	2.32	261	2.30	322	2.15	383	2.13
79	2.10	140	2.17	201	2.03	262	2.02	323	2.03	384	1.95
80	2.03	141	2.28	202	1.98	263	2.48	324	1.75	385	2.13
81	1.92	142	2.00	203	2.12	264	2.05	325	1.98		

References

About RFID readers. (2005). Retrieved July 8, 2005, from RFID 101: Your information guide on radio frequency identification Web site: http://www.rfid-101.com/rfid-readers.htm

About RFID tags. (2005). Retrieved July 8, 2005, from RFID 101: Your information guide on radio frequency identification Web site: http://www.rfid-101.com/rfid-tags.htm

Allen, W. (2005, April). *Understanding RFID (RFID 101)*. Retrieved July 11, 2005, from R. Moroz Ltd. Web site: http://www.rmoroz.com/2nd_Conference_pdf/WS%20-%201A%20UNDERSTANDING%20RFID.pdf

Alfaro, J. A., & Corbett, C. J. (2003). The value of SKU rationalization in practice (the pooling effect under suboptimal inventory policies and nonnormal demand). *Production and Operations Management*, *12*(1), 12-29

Asif, Z., & Mandviwalla, M. (2005). *Integrating the supply chain with RFID: a technical and business analysis*. Retrieved June 29, 2005 from http://www.ebi.temple.edu/programs/RFID/RFIDSupplyChain.pdf

Banks, J., Carson, J. S., Nelson, B. L., & Nicol, D. M. (2005). *Discrete-event system simulation* (4th ed.). Upper Saddle River, NJ: Pearson Education.

Benjaafar, S., Cooper, W. L., & Kim, J. S. (2005). On the benefits of pooling in production-inventory systems. *Management Science*, *51*(4), 548-565.

Bushe, F. (2004, January 06). Modelling health care. *The Medical Post*, News. Retrieved August 10, 2006 from http://www.medicalpost.com/news/article.jsp?content=20040102_161503_3120

Carter, M. (2002, April). Diagnosis: Mismanagement of Resources. *OR/MS Today*, *29*(2). Retrieved August 10, 2006 from http://www.lionhrtpub.com/orms/orms-4-02/frmismanagement.html

Carter, M. (2004, December 14). *Operations research in health care or who let the engineer into the hospital*. Retrieved August 10, 2006, from Waterloo Institute for Health Informatics Research Web site: http://hi.uwaterloo.ca/hi/WIHIR_Research_Seminar_Michael_Carter.htm

Carter, M. (2006). *Welcome to the Health Care Productivity Research Lab*. Retrieved August 10, 2006, from Health Resource Modelling, Department of Mechanical and Industrial Engineering, University of Toronto Web site: http://www.mie.utoronto.ca/labs/health/

Collision definition. (2005, September). Retrieved August 24, 2006, from http://www.bellevuelinux.org/collision.html

Datta, S. (2005). *Radio Frequency Identification made easy*. Retrieved June 15, 2005, from MIT forum for supply chain innovation Web site: http://supplychain.mit.edu/innovation/docs/RFID%20Made%20Easy.pdf

DEA: Data Envelopment Analysis, technique for determining relative productivity. (1996, January 27). Retrieved August 10, 2006, from http://www.emp.pdx.edu/dea/wvedea.html

Di Paolo, M., Furr, W., Nhi, N. H., & Kim, K. T. (2005). *RFID: Replacement or Supplement to Bar Codes*. Retrieved June 5, 2005, from citeseer.ist.psu.edu/403591.html

Eppen, G. D. (1979). Effects of centralization on expected costs in a multi-location newsboy problem. *Management Science*, *25*(5), 498-501.

Fahlstrøm, E., Grimnes, S., & Johannejen, N. H. (2006). An interdepartmental, standardized equipment pool. *Journal of Nursing Management*, *14*(2), 148-154.

Finkenzeller, K. (2003). *RFID Handbook* (2nd ed.). Chichester, UK: John Wiley & Sons.

Gentles, W. M. (2000). The central equipment pool, an opportunity for improved technology management. *Biomedical Instrumentation and Technology*, *34*(3), 213-216.

Gragg, J. (2003, November). *The emergence of RFID technology in modern society*. Retrieved June 25, 2005, from http://islab.oregonstate.edu/koc/ece399/f03/explo/gragg.pdf

Grand River Hospital. (2005). Retrieved October 10, 2005, from Grand River Hospital Web site: http://www.grandriverhospital.on.ca/

Hoffman, R. D. (2002). *Infusion pump*. Retrieved September 19, 2006, from the Animated Software Company Web site: http://www.animatedsoftware.com/pumpglos/infusion.htm

Landt, J. (2001, October). Shrouds of time, the history of RFID. *AIM*, Retrieved July 6, 2005, from http://www.aimglobal.org/technologies/rfid/resources/shrouds_of_time.pdf

Law, A. M., & Kelton, W. D. (1991). *Simulation modeling & analysis* (2nd ed.). New York, NY: McGraw-Hill.

Law, A. M. (2006). *ExpertFit distribution-fitting software*. Retrieved August 10, 2006, from Averill M. Law and Associates Inc. Web site: http://www.averill-law.com/ExpertFit-distribution-fitting-software.htm

Naylor, T. H., & Finger, J. M. (1967). Verification of computer simulation models. *Management Science*, *14*(2), 92-101.

Pasin, F., Jobin, M. H., & Cordeau, J. F. (2002). An application of simulation to analyse resource sharing among health-care organizations. *International Journal of Operations and Production Management*, *22*(4), 381-393.

RFID. (2005). Retrieved June 18, 2005, from International Paper Web site: http://glossary.ippaper.com/default.asp?req=knowledge/article/489&catitemid=38

Shepard, S. (2005). *RFID Radio Frequency Identification* (1st ed.). New York, NY: McGraw-Hill.

Simul8 Corporation. (2006). Retrieved August 10, 2006, from Simul8 Corporation Web site: http://www.simul8.com/index.htm

Stockman, H. (1948). Communication by means of reflected power. *Proceedings of the Institute of Radio Engineers*, 1196-1204.

Swain, J. (2005). *Simulation software survey*. Retrieved August 14, 2006, from OR/MS Today Web site: http://www.lionhrtpub.com/orms/surveys/Simulation/Simulation.html

Tag-it FAQs (2006). Retrived September 19, 2006, from Texas Instruments Incorporated Web site: http://www.ti.com/rfid/shtml/cust-support-faqs.shtml#Tten

Tagaras, G. (1989). Effects of pooling on the optimization and service levels of two-location inventory systems. *IIE Transactions (Institute of Industrial Engineers)*, *21*(3), 250-257.

Tagaras, G., & Cohen, M. A. (1992). Pooling in two-location inventory systems with non-negligible replenishment lead times. *Management Science*, *38*(8), 1067-1083.

Tagaras, G. (1999). Pooling in multi-location periodic inventory distribution systems. *Omega*, *27*(1), 39-59.

Understanding Radio Frequency identification (RFID). (2004, November). Retrieved April 10, 2005, from R. Moroz Ltd. Web site: http://www.rmoroz.com/rfid.html

Socio Technical Systems. (2006). Retrieved August 30, 2006, from http://www.strategosinc.com/socio-technical.htm