UNIVERSITY OF ALBERTA

EMERGENCY DEPARTMENT PROCESS FLOW IMPROVEMENT BASED ON EFFICIENT ARCHITECTURAL LAYOUT, LEAN CONCEPT AND POST-LEAN SIMULATION

By

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Abstract

Long waiting times in Emergency Departments (ED) have been an issue in Canadian hospitals for years. Many factors have contributed to the excessive waiting time, including the current design scheme which is known architecturally as the "Funnel Design Scheme." Current architectural and engineering practice lacks standards to quantify the effect of ED design and ancillary departments on waiting time and Length of Stay (LOS). This research focuses on assessing the architectural standards of ED on the basis of a patient-focused environment. The objective is to optimize the space requirement to reduce waiting time following what is called "universal zero delay treatment." The proposed methodology uses two techniques: a) a statistical analysis of forty two ED architectural designs, and b) the application of Lean Healthcare combined with Post Lean Simulation which offers an opportunity to evaluate the potential impact of different interventions on patient flow and throughput. The proposed methodology is tested through a case study and interviews with healthcare professionals.

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List of Acronyms

CTAS	Canadian Triage and Acuity Scale
DES	Discrete Event Simulation
DI	Diagnostic Imaging
ED	Emergency Department
LOS	Length of Stay
LWBS	Left Without Being Seen
OR	Operating Room
VSM	Value Stream Mapping

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Chapter I Introduction

1.1. Motivation of the Research

Emergency Department waiting times impact medical professionals' overload and access to timely patient care, and contribute to patient safety concerns. The ED congestion and lengthy waiting time is due to a number of factors that can be categorized in two main branches: 1) Operational challenges, such as shortage of beds, ED LOS for admitting patients to hospitals, increased complexity or acuity, and an inefficient functional process. 2) Architectural design and layout that does not allow for efficient practice within the ED.

LOS, or the median amount of time spent in the ED, includes time spent waiting[1] for initial physician assessment as well as diagnostic tests or procedures and treatments; LOS in Canada was just over two hours in 2003-2004 and it varied by the time of the day, as shown in Figure 1, morning ED visits had shorter LOS, either because of low influx or patients were discharged at faster rate than during the rest of the day or night (Canadian Institute for Health Information, 2005).

[1] Time spent in ED is being logged once patient's information is entered in the system, this is done at the Registration Stage when patients present to the ED.

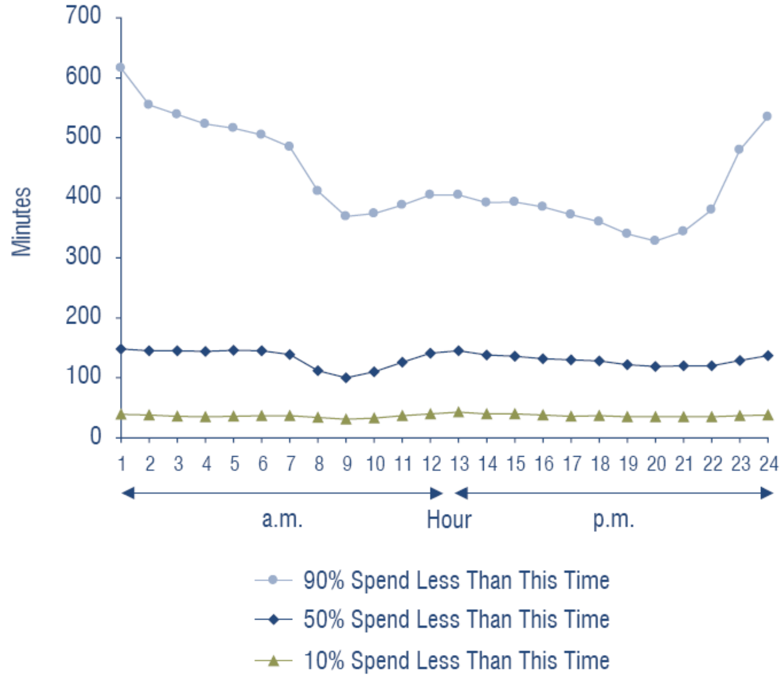

Figure 1 LOS time distributed over the hours of the day (Canadian Institute for Health Information, 2005).

In general, in 2003-2004 half of the patients visiting EDs waited 51 minutes or less to be seen by a physician after being triaged. There seems to be a correlation between the time a patient waits to see a physician and his severity level.

Overall, high severe level patients had the shortest proportion of waiting time in EDs to be seen by a physician in 2003-2004. On the other hand, patients triaged as non-urgent spent the largest proportion of time waiting for a physician.

While long waiting times are a serious concern, research assessing specific ED crowding interventions has been limited. In this context, developing an ED process model to identify root causes of excessive waiting times and resources needed in EDs provides an opportunity to evaluate the potential impact of different interventions on ED patient flow and throughput. The current healthcare delivery system is unable to provide service in an efficient and functional way;

continuing care delivery in the same traditional methods is not sustainable. The healthcare system needs a fundamental change of care systems to provide efficient service and care. As healthcare is developing at an increasing rate, this research challenges the majority of traditional design concepts and principles that have not developed at the same rate in the last two decades as the broad healthcare field. While, in most cases, ED design is an overreaction to the current and location-specific conditions and environment, it should be quick to respond to changes.

1.2. Research Objectives

To understand the functional process and identify inefficiencies and bottlenecks that result in excessive waiting times in EDs, the following two methods are applied: a) An investigation on ED process design that includes mapping and analysis of process components which enables better understanding of not only the effect of functional requirements but also the standards' requirements. This step is a prerequisite for examining the proposed process change and assessing the impact of other ED service-related departments. b) The application of decision-making and modeling tools, Lean Healthcare combined with simulation, offers an opportunity to evaluate the potential impact of different interventions on patient flow and throughput. The objective of the above proposed methodology is to arrive at a new *Streamlined Design Scheme* that replaces the existing *Funnel Shape Design Scheme*, which is common in the current architectural practice of designing EDs, while assessing the architectural standards of ED design on the basis of patient-focused environment. While doing so, waiting time is reduced following what is called "universal zero delay treatment." The research presented in this thesis focuses on assessing the architectural and engineering standards of ED on the basis of a patient-focused environment and incorporates new design principles that are not specific to the healthcare field; but applicable to making functional processes more efficient and the physical environment more user friendly.

The focus of this research was to investigate the effect of implementing Lean Healthcare on the ED process; such analysis would verify the feasibility of the proposed solutions and provide quantifiable results. In addition, ED ancillary departments have an effect on waiting times in ED. This type of co-relationship and inter-departmental process flow has been overlooked in current architectural design standards.

The objectives of this research were to:

- Arrive at a *Streamlined Design Scheme* that replaces the existing *Funnel Design Scheme*.
- Achieve a reduction in average LOS, which will add a positive value to patient experience while in the ED.
- Identify the process steps that are necessary and valuable to the patient's experience.
- Eliminate waste in all of its aspects.
- Assess the architectural and engineering standards of ED on the basis of a patient-focused environment.
- Optimize the space requirement while reducing waiting time following what is called "universal zero delay treatment."

The proposed approach also tests several scenarios in the simulation models to quantify value proposition, and measure other departments' service time impact on the ED process.

1.3. Methodology

A methodological approach in addressing ED waiting times was established with the Canadian Triage and Acuity Scale (CTAS). David (2010) emphasized the physician's "initial assessment" as being the measuring factor of waiting time, and established targeted times for measurement it. However, these times were not intended to be standards, but rather, a means of measuring ED performance and comparing various ED waiting times. The following are the instituted targeted times based on patients' CTAS triaged levels (David et al., 2010):

CTAS I Resuscitation: immediate (at 98%)

CTAS II Emergent: 15 minutes (at 95%)

CTAS III Urgent: 30 minutes (at 90%)

CTAS IV Less-Urgent: 60 minutes (at 85%)

CTAS V Non-Urgent: 120 minutes (at 80%)

The ED is a complex process with multiple interactions and inter-departmental relationships influencing patient throughput. Consequently, the following two methods that address the root causes of excessive waiting time need to be developed: a) An analysis of ED process design changes and examination of the impact of ED service-related departments. For example, an evidence-based approach to eliminate "triage" and fast forwarding patients to examination rooms for treatment and further examination will be tested. b) The application of Lean Healthcare combined with simulation that captures ED interactions will need to be developed and evaluated through comparative analysis.

Assessing the architectural standards of ED design is conducted on the basis of a patient-focused environment. The following standards were used and examined for the purpose of this study:

- Huddy, Jon (2006), "Emergency Department Design-A Practical Guide to Planning for the Future,"*American College of Emergency Physicians*
- The Facility Guidelines Institute (2010), "Guidelines for Design and Construction of Health Care Facilities, "*ASHE (American Society of Health Care Engineering) of the American Hospital Association,* ISBN: 978-0-87258-859-2

In addition to the above mentioned standards, a statistical analysis and survey were conducted of 42 ED designs that illustrate the common themes and differences in ED layouts.

1.4. Thesis organization

Chapter 2 contains a literature review. There are four areas in which the literature has been reviewed: the history of ED design, ED's current state in Canada and the world, the ED process, and best practice in Lean Healthcare and Post-Lean Simulation. Chapter 3 discusses the methodologies and implementation techniques that have been used in this research. It includes statistical analysis of ED architectural layouts, process design change and principles, implementation techniques and a case study, and results discussion. Chapter 4 concludes the paper and discusses future study.

2.1 Architectural Design of Healthcare Related Study

2.4.1 Overview of the History of ED Design

Historically, hospitals and healthcare facilities have been established in different forms, sometimes as independent entities and in most cases as integrated buildings with other types of practices. In the Islamic Golden Age, the word "Bimaristan"[2] indicated a hospital in the modern sense, an establishment where the ill were hospitalized and treated by trained staff. In this way, Islamic medicine was the first to make a distinction between a hospital and other different forms of healing temples, sleep temples, hospices, psychiatric hospitals and leper houses, all of which in ancient history were more concerned with isolating illness and insanity from society "rather than to offer them any way to a true cure." The medieval Bimaristan hospitals are thus considered "the first hospitals" in the modern sense of the word (Gorini, 2002).

The Bimaristan hospitals, like the Emergency Departments in today's health systems, treated mainly severely-ill people. Those facilities were not only unique in establishing a scientific and ethical method to treat patients, but also in creating healing spaces based on concepts considered today to be the most innovative ways of treating patients. For example, two main principles that concern patients' satisfaction were applied in the Bimaristan: healing gardens and patient-focused design elements and spaces. These two principles were the basis of the Bimaristan Al-Nouri of Damascus, built in the reign of Nour Eddin Zanki in 1154 AD. The Bimaristan was meant to be both a medical school and hospital. It witnessed some architectural annexing in the 13^{th} c.ad as a means of expansion and underwent several restoration works in later periods. It is famous for its decoration, artistic elements and architecture (Rihawi, 1979; Allen, 2010).

[2]**Bimaristan** is a Persian language word (بیمارستان bīmārestān meaning hospital, with Bimar-from Middle Persian of vīmārorvemār meaning "sick" plus [[-stan]]as location and place suffix. (Source: http://www.business.reachinformation.com/bimaristan.aspx)

Figure 2 and Figure 3 show the interior spaces of the Bimaristan and the elements that contributed to enhancing patients' experience and their healing process, which include:

- The main court yard with water features and greenery that help in the healing process.
- Iwan, or "open room" that is decorative and in direct connection with outdoor space.

(Photos are courtesy to ArchNet Digital Library, www.archnet.org)

The Bimaristan design provides a controlled environment through shaded spaces, greenery, and water features that comfort and satisfy patients. A unique experience for patients and family members, the main entrance provides waiting spaces and a relaxing environment, as seen in Figure 4.

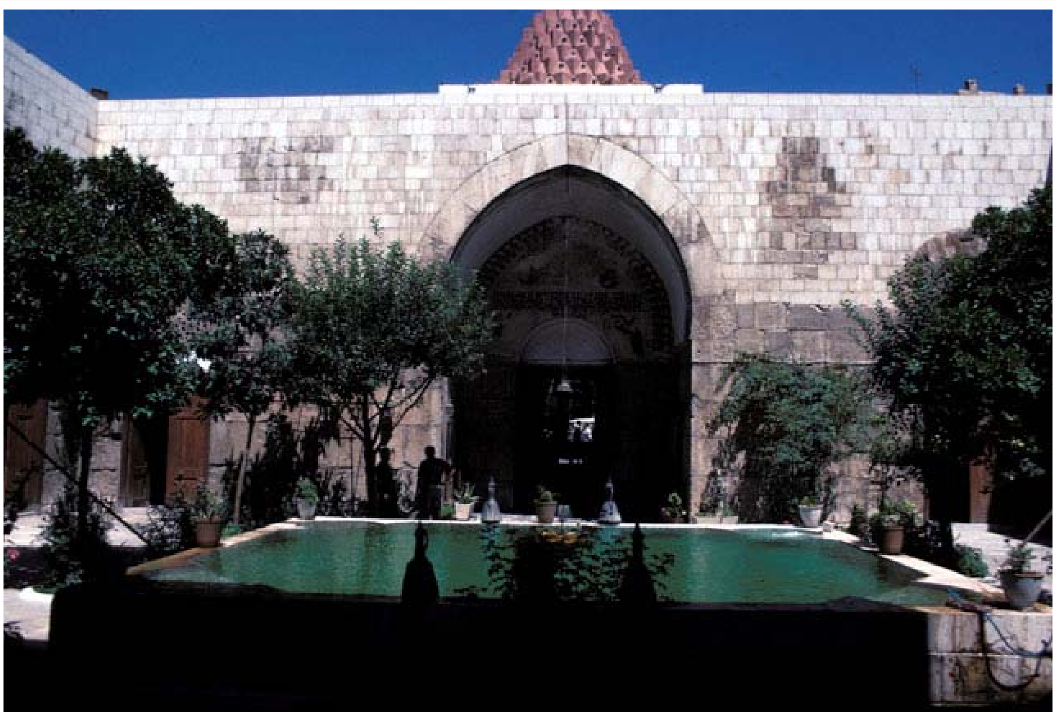

Figure 2 The Bimaristan of Damascus, the main entrance and court yard.

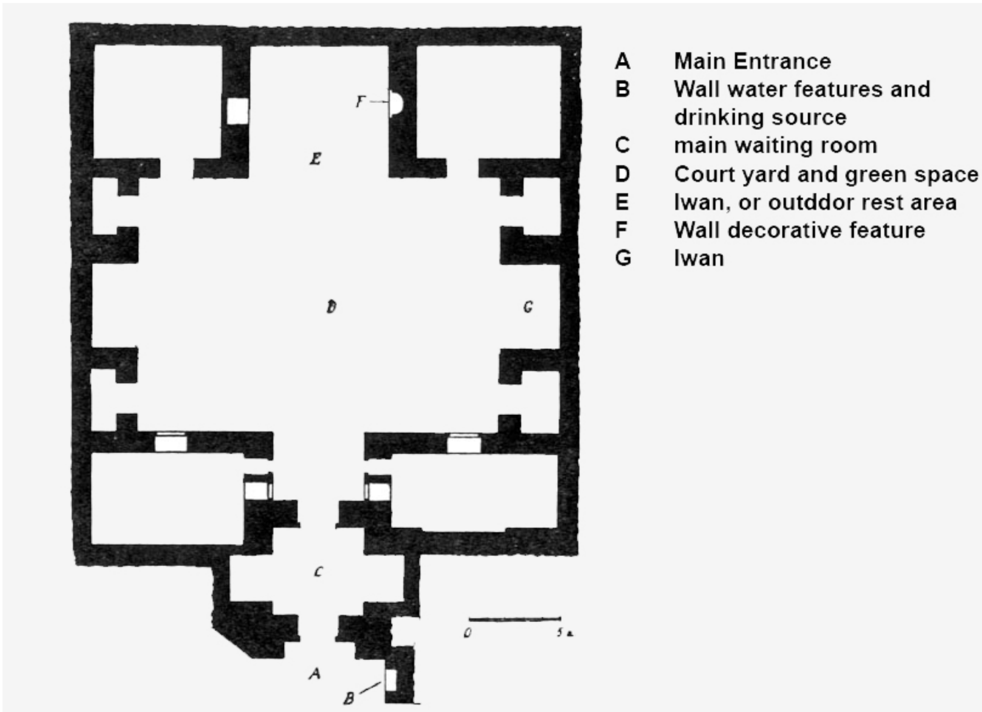

Figure 3 The plan of the Bimaristan of Damascus.

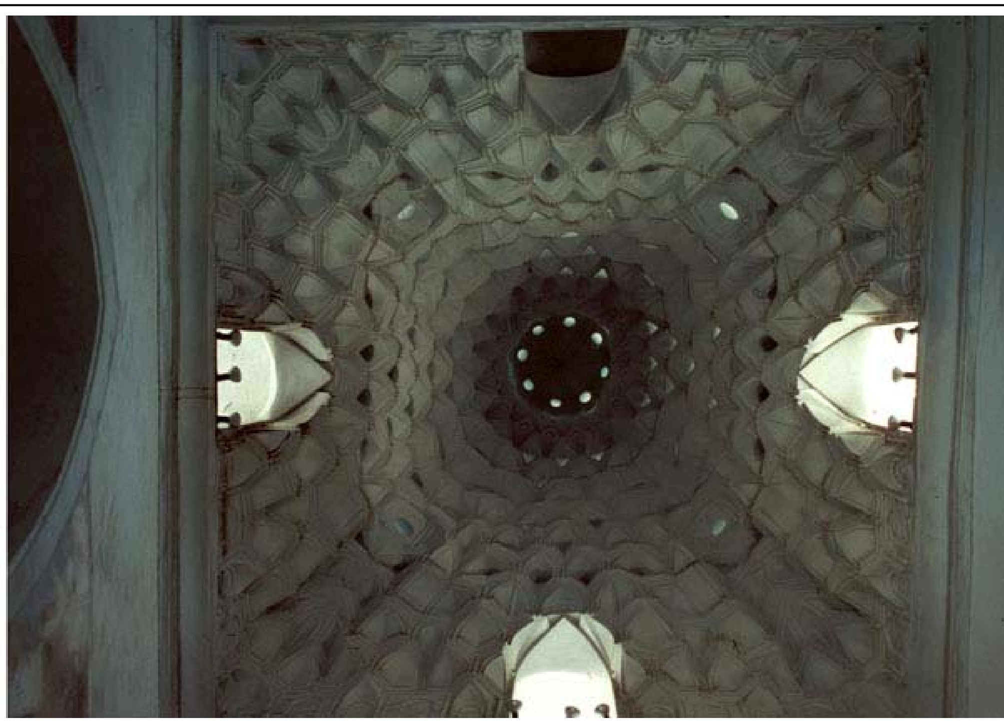

Figure 4 The main entrance that provides waiting spaces and a relaxing environment.

In the book of "Emergency Department Design-A Practical Guide to Planning for the Future", published by American College of Emergency Physicians in 2006, Huddy illustrated the history of ED modern Design in the period from 1945 until 1990s: In the modern architecture, more specifically in the post-war era (1945-1960), Emergency Room (ER) design consisted of a single room accident ward with limited materials, equipment, and design features. It is estimated that 80% of ER visits were for non-life threatening conditions, 15% for emergencies requiring immediate attention, and 5% for treating critically-ill patients. In the late 1960s and early 1970s, ED design emerged as an architectural specialty as emergency care emerged as a medical speciality. This era witnessed EDs that were physically and operationally disastrous due to the absence of insight into emergency care, failure to incorporate care givers in the design process, and rapidly changing services. In the late 1970s, the majority of healthcare construction projects were responding to the immediate need for medical office buildings that, in reality, were general office buildings with examination rooms. On the other hand, the early 1980s witnessed hospital projects and ED designs that were technologically complex. However, many of these designs did not involve healthcare professionals or incorporate functional inputs of how emergency care should be delivered. ED designs of this time were not functional due to limited understanding of care requirements and the rapidly changing medical field. Furthermore, these ED designs had little effect on functional efficiency and patient throughput times due to low patient volumes. Not until the 1990s was a swell of ED volumes witnessed. In the late 1980s and early 1990s, more architects included care givers in the design process, and as a result healthcare architectural firms gained knowledge about ED operational workflow and completed more efficient ED designs. At the same time, this period witnessed the emergence of ED specialities that dictated entirely separate care components, or pods, for different specialities. The specialized care components eradicated the flexibility of overflow into other patient care units and increased physical, equipment and staffing resources required for running all ED components. Overspecialization and segregation of ED modules affected negatively the flexibility, efficiency and effectiveness of EDs designed in the 1990s. (Huddy, 2006).

History of ED Practice is presented in Appendix A.

2.2 Emergency Department Components and Process and Flow

EDs were primarily established to treat seriously ill and injured patients who needed immediate care, 24 hours a day, seven days a week. In practice, however, EDs strive to provide timely care to all patients regardless of why they are seeking assistance (CAEP, 2001).

Patient flow is not the same in every ED. However, in most cases, the following stages are common in the assessment and treatment of ED patients. Figure 5 illustrates the main stages of the ED process:

Patient Arrivals: The process starts when patients arrive either by walking in or by ambulance. Patients' arrival is unexpected and not scheduled. Immediate assessment is required; sometimes treatment should be immediate depending on the patient's condition. The majority of patients arriving at the ED -- more than 70% -- come at peak hours which extend from 11 am to 11 pm, as indicated in Figure 9.

Triage[3]**:** Walk-in patients go through a process of being triaged by a nurse, where they are prioritized or routed to care according to their CTAS level and their order of arrival within each level. Patients can be "under-triaged" (when assigned a triage level lower than the patient's actual acuity) which might compromise patient safety, while over-triaged patients (when assigned a triage level higher than the patient's actual acuity) result in denying access of other

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[3] "*a***:** the sorting of and allocation of treatment to patients and especially battle and disaster victims according to a system of priorities designed to maximize the number of survivors *b***:** the sorting of patients (as in an emergency room) according to the urgency of their need for care" (Merriam-Webster, 2011). Triage first used in " 1727, "action of assorting according to quality," from Fr. triage "a picking out, sorting," from O.Fr. trier " (Dictionary.com, 2011)

patients to timely care (Dong, 2005). After being triaged, patients are registered before being admitted to a physician in an examination room. If the patient arrives in an ambulance, the triage and registration steps are different, but an assessment is still done in the ED; all patients assigned a CTAS I category proceed directly to a main ED bed, whereas CTAS II and III patients proceed to the waiting area. If a bed is available, it is assigned to the next patient in the waiting area. When all beds are occupied, CTAS II and III patients remain in the waiting area until one of the beds becomes available.

Waiting Area: There is one waiting area in most EDs, sometimes two if the ED is designed for a *fast track* model that places CTAS IV and V patients in a separate waiting room and treats them with separate processes. While waiting for a bed, some patients may opt to leave without being seen by a physician[4].

Main ED: The main ED consists of beds, attending physicians, and a hallway area consisting of boarding spaces. Once a patient occupies a main ED bed, the succeeding process is broken down into three steps. First, the patient spends time with a physician for an initial assessment and may have to wait if all physicians are occupied with other patients. CTAS I and II patients spend time with the physician, whereas CTAS III, IV and V patients spend time without the physician, during which time treatment and diagnostic tests are conducted. Finally, the patient spends more time with the physician before being admitted or discharged. These times do not include boarding time, which is defined as the amount of time admitted patients spend in the hallway while awaiting an inpatient bed.

Ancillary Departments: One of the frustrations for ED physicians is overcrowded emergency departments. Intrinsic to emergency management is the need to work with other specialties and departments, the results either

[4] Percentages of patients who presented to the ED and left without being seen in Canadian provinces are illustrated in Table 3. It has been established that there is a direct correlation between ED overcapacity and leaving without being seen (Yoon, 2003). According to trends published by Khare, 2008, it is believed that the decision of leaving without being seen is based on two factors: a patient leaving without being seen per ESI level (the Emergency Severity Index triage system used in US which is equivalent to CTAS acuity scale in Canada) and a threshold time (how long the patient will wait before leaving without being seen).

being rewarding, or adding difficulties to the ED functional process. The Surgical Department, Diagnostic Imaging, and Laboratory are major ancillary departments on which the ED depends to diagnose and treat patients. These departments affect the process flow as they suffer from (Huddy, 2006):

- Redundant capacity, as required resources are not prepared to provide needed service in a timely manner;
- Insufficient communication to guarantee that other departments are ready to provide services for expected patients;
- Ineffective services that either consume more than required time or require rework.

Studies reflecting evidence-based clinical guidelines have been conducted. Maykut (2004) studied the effect of the development and implementation of critical pathways for Atrial Fibrillation on decreasing LOS in ED, and recommended chest x-rays to rule out critical situations.

Admission: Patients who are discharged from the ED can be classified into three categories: patients who are discharged to be admitted to the hospital, patients who leave ED to go home, or patients who have died. Patients who are discharged and proceed to admission to the hospital sometimes wait for an inpatient bed; if an inpatient bed is not available, patients will board and thus occupy a bed in hallway space until a bed becomes available in the appropriate inpatient unit. CTAS I patients exit the ED into an inpatient bed and bypass boarding because of their severity index. The remainder of patients also proceed to exit the ED by being discharged, or having died.

Exit ED: All admitted or discharged patients leave the ED. Discharging patients to Inpatient Unit is not an easy process, as patients often wait for hospital bed placement due to the following (Huddy, 2006):

- Discharge process is delayed so other patients cannot depart at the expected time.
- Poor communication exists between the ED and Inpatient Unit regarding bed availability and scheduling;

- Bed preparations take longer than expected which delays patients' placement;
- Specific beds are suitable for specific patients; tracking system is insufficient to match types of available beds with types of patients for placement.

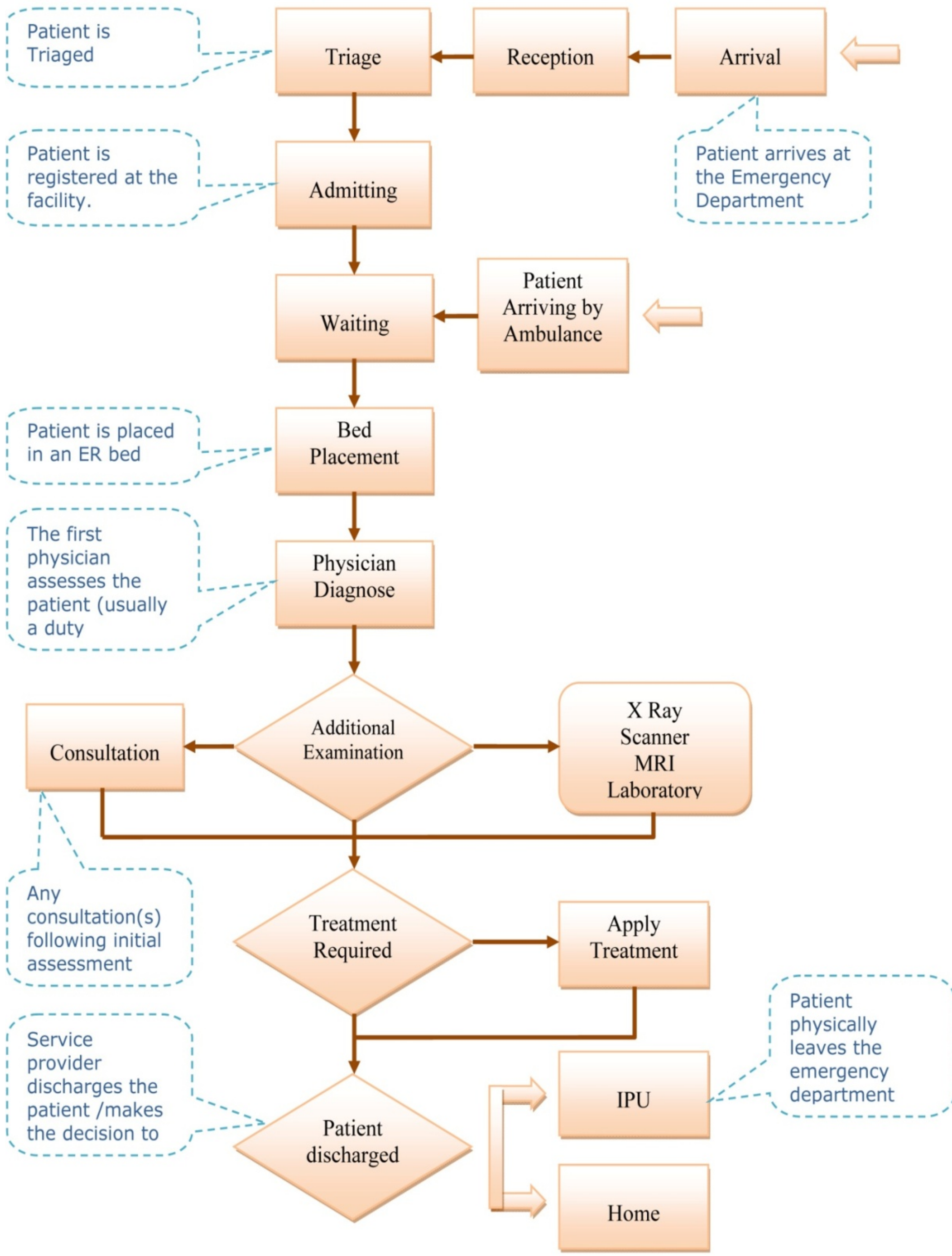


Figure 5 The generic process stages of main ED and ancillary departments that patients go through for examination and treatment.

2.3 Best Practice in Lean Healthcare and Post-Lean Simulation

The healthcare industry faces tremendous changes due to new technologies that result in new challenges and complexities in designing and running healthcare facilities. Simulation and modeling are becoming important tools in designing and planning a healthcare facility.

2.3.1 Lean Healthcare

Lean Thinking is broadly recognized in care delivery systems around the globe. Toyota Motor Corporation standardized its manufacturing process steps by implementing "Lean production system," a production method found in Japan. Based on Lean strategy, all elements of the production system are designed to create a continuous value added process while eliminating waste (Black et al., 2008). Lean Healthcare, on the other hand, is a fairly new strategy that aims at improving process and productivity (Young & McClean, 2008) by eliminating inefficiencies and thus increasing value added activities for patient care(Leslie et al, 2006). In addition, the approach to process focuses on waste and reducing waiting times (Mazur et al., 2008). As Scott (2011) illustrated in his dissertation, the seven types of waste observed in the Lean Healthcare system is similar to what is found in manufacturing, which includes:

1. Overproduction of duplicating charts and forms containing the same patient information.
2. Wait time in process steps
3. Transportation or movement
4. Motion due to lack of organization.
5. Inventory due to overstocking.
6. Over processing of procedures that do not add value to the patient treatment, and
7. Defective products seen in medication errors and faulty tests.

"There is evidence that improvement methods are being applied in healthcare given the fact that Lean has become a vital element in a world that is focused on process, articulated by performance measures and, increasingly, directed by a core set of values" (Young & McLean, 2009). Rovert (2007) reported that "the president of the Institute for Healthcare Improvement estimates that the total cost of healthcare production waste is 30 to 40% waste; that is a waste of time, money, and material resources." Cost and quality improvement can be achieved by eliminating waste and non-value-added steps in the work processes.

Lean systems help identify process flows and waste (waiting) for improvement. Improved flows increase the value-added work percentage, and reduce work errors, eventually creating greater patient and staff satisfaction (Black et al., 2008). Flows can be represented graphically in a Value Stream Map (VSM), "a diagram that shows the series of steps required bringing a product of service to a customer" (Dennis, 2002). The current state map that records the current practice and entities' usage rates is created; it helps review the processes' characteristics at a facility-wide level. A future state map is then created to illustrate the process improvements that have been made (Green Suppliers Network, n.d.). Waiting is considered waste of time in the Lean system, particularly when patients spend time in long queues for examination and treatment (Black et al., 2008). Virginia Mason Emergency Department improved its process by implementing Lean principles that reduce wait time from 20 minutes to 6 minutes (Womack et al., 2005). Dickson (2005) reported that implementing Lean principles at the Emergency Department, University of Iowa Hospital helped achieve a continuous decrease in average LOS and increase in patient satisfaction. Standardizing care processes through lean thinking is recommended to address the core Healthcare concerns, just as Toyota standardized its manufacturing process steps (Jones et al., 2006).

Healthcare processes suffer from inefficiencies and process bottlenecks due to unbalanced work flow and waste, Lean streamlines the process and eliminates waste, consequently improving work flow (Fine et al., 2009). Lean in Healthcare helps identify challenges to effectiveness and eliminates waste; as processes improve, quality of care improves as well (InfoFinders, 2010/2011). The Lean healthcare system consists of strategies that concern eliminating inefficiency; as a result, more value-added time can be dedicated to process activities, and consequently, to patient experience (Piccolo, 2010). To improve quality and productivity in healthcare facility processes, Total Quality Management, continuous quality improvement, and balanced score cards techniques have been implemented in the last few decades with the hope to arrive at remarkable achievements (Scott, 2011). Process improvements can also be achieved through other Lean techniques, such as standard work that details the turn over time of tasks performed so that tasks can be balanced between process stages. These strategies help reduce turnover time, improve flow, and result in a more efficient process (Grout et al., 2010). In addition to streamlining workflow and reducing waste, the lean system recommends the adoption of a new drug transfer model, alternates technicians to avoid fatigue, and reduces their travel time (Solanki, 2010). These strategies have resulted in remarkable capacity expansion as well (LaGanga, 2011). Jimmerson states (2009) that improvements are associated with the implementation of Lean in organizations. These improvements include: a decrease in operational cost, a better work environment and increase in patient satisfaction, productivity, and leadership abilities (Jimmerson, 2009).

2.3.2 Post-Lean Simulation

Healthcare delivery can be improved by applying the same simulation and modeling techniques that have proven successful in other fields or industries that address resource use and waiting times (Yerravelli, 2010). The simulation tool is a widespread application in many fields, and it is becoming an important tool in addressing issues in the healthcare field (Eldabi, 2010). The usefulness of the simulation model is in forecasting planning, optimizing human and physical resources, and improving efficiency before implementing the proposed changes in real life (Saunders et al., 1989). Simulation modeling requires the establishment of three policies to be successful in influencing the healthcare field: the model should be an accurate reflection of the real-life setting, decision makers should be represented in the participating user group , and finally the environment in which the modeling process takes place should incorporate actual healthcare context and understanding (Young et al., 2009).

Simulation modeling helps researchers, administrators and policy makers identify root causes of ED waiting times and explores various problem-solving scenarios. The modeling components of the ED acute care system can be represented in the simulation model components as input, throughput, and output (Asplin et al., 2003). Discrete Event Simulation is used to model the process of patients passing through the ED. Discrete Event Simulation generates a list of time epochs in minute units; statistics are collected from the time period that the model is run by which captures the process randomness, such as arrivals into the ED, wait times, and other patient characteristics. The standard deviation, which is used to estimate the width of the associated 95% Confidence Interval, is also collected (Law & Kelton, 1991). Holm (2010) demonstrated through a simulation model that an increase of 45% in patient volume would not compromise the flow in ED. This simulation tested different scenarios to increase both nurse and physician capacity to a sufficient level to meet the increased needs.

In evaluating different interventions on the ED process, a simplified model was developed where staffing levels and bedside registration was tested against LOS and waiting times; improvements were made which will be validated in real application (Beck et al., 2009). Tow simulation models investigated the effect of replacing a triage nurse by a physician on the ED wait time; the results showed a reduction from 117 minutes to 26 minutes (Holm et al., 2009). The ED process is affected by different departments and specialties, and the stochastic nature of patient arrivals challenges ED capacity planning for patient treatment. Discrete Event Simulation provided a tool to review the sensitivity analysis of a model aimed at comparing tow operating-room-allocation policies; it showed that average ED wait time decreased when access to operating rooms increased (Ferrand, 2010). Simulation helped determine the additional ED resources needed due to fluctuation in patient volume, and it also identified different scenarios that best meet the demand (Holm, 2010). Brailsford (2010) argued if an integrated approach to simulation when combining System Dynamics with Discrete Event[5] Simulation is feasible in the healthcare applications; he demonstrated the benefits and challenges of this approach (Brailsford et al., 2010). In a study that used a system dynamics simulation model, and aimed at investigating the causes of long waiting times for admission to the Accident and Emergency unit, Lane et al., (2010) concluded that a decrease in bed numbers do not augment waiting times for patient examination by a physician (Lane et al., 2010).

The concept of "bottlenecks" is essential in addressing the issues of ED overcrowding and long waiting time as they affect LOS (Khare et al. 2008). A computer simulation model was developed to compare the effect of two operational interventions on ED LOS: increasing the number of ED beds and increasing the rate at which admitted patients leave the ED. The simulation outcome analysis concluded that increasing the number of ED beds had no effect on LOS; however, increasing the rate that the ED admitted patients to the hospital did. A study by Polevoi et al. (2005), aimed at analysing the factors associated with patients who leave without being seen (LWBS), simulation allowed ED bottleneck intervention to be assessed. Not only did LOS increase when more beds were added to the ED, but also the rate of patients admitted to the hospital increased. ED simulation modelling help resolve department future capacity planning issues, and demonstrate the successful design strategies in establishing sustainable improvement (Exadaktylos et al. 2008).

2.4 Examination of the State of Emergency Department in Canada

2.4.1 Assessing Severity in Canada

Assessed patients visiting EDs in Canada in 2003- 2004 revealed the following numbers: only 0.5% of those arriving at EDs were triaged as the most severe level of CTAS I (e.g., major trauma, shock, severe respiratory distress). The majority

[5]"Typically, DES is used for modeling queuing systems where stochastic variability is important. On the other hand The Surgical Department is a more strategic tool, used at a much higher level for understanding overall system behavior," (Brailsford et. al., 2010).

of cases (57%) were assessed as either less-urgent with CTAS IV (e.g. chronic back pain, not sudden headache, mild allergic reaction) or non-urgent with CTAS V (e.g. sore throat, menses, isolated diarrhea). **Figure 6** shows the distribution of the patients visiting EDs according to their CTAS triage levels (Canadian Institute for Health Information, 2005).

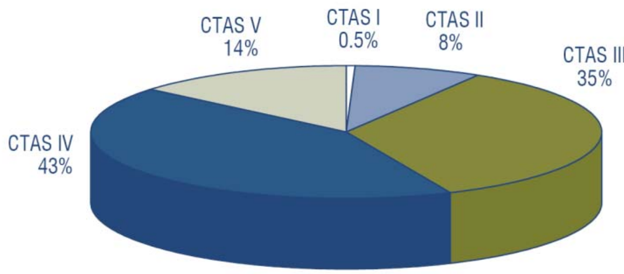


Figure 6 Distribution of ED patients' severity levels (Canadian Institute for Health Information, 2005).

To ensure that seriously ill patients receive immediate care, the Canadian Triage and Acuity Scale (CTAS) classifies the severity of ED patients' illnesses. For example, the CTAS categorizes the ones requiring immediate resuscitation as CTAS level I, patients with broken bones often can wait for a short period of time for treatment may be classified as CTAS III or IV. In general, the CTAS classifies patients into five different levels (David, 2008):

CTAS I: Requires resuscitation and includes conditions that are threats to life or at imminent risk of deterioration, requiring immediate aggressive interventions (for example, cardiac arrest, major trauma, or shock states).

CTAS II: Requires emergent care and includes conditions that are potential threats to life or limb function requiring rapid medical intervention or delegated acts (for example, head injury, chest pain, gastrointestinal bleeding, abdominal pain with visceral symptoms, or neonates with hyperbilirubinemia).

CTAS III: Requires urgent care and includes conditions that could potentially progress to serious problems requiring emergency intervention, such as mild-moderate asthma or dyspnea, moderate trauma, or vomiting and diarrhea in patients younger than 2 years.

CTAS IV: Requires less-urgent care and includes conditions related to patient age, distress, or potential for deterioration or complications that would benefit from intervention or reassurance within one to two hours, such as urinary symptoms, mild abdominal pain, or ear-aches.

CTAS V: Requires non-urgent care and includes conditions in which investigations or interventions could be delayed or referred to other areas of the hospital or healthcare system, such as a sore throat, menses, conditions related to chronic problems, or psychiatric complaints with no suicidal ideation or attempts (Implementation Guidelines for the Canadian Emergency Department Triage & Acuity Scale, 1998).

2.4.2 Assessing Triage

In a study aimed at evaluating a memory triage (evaluation conducted based on nurse experience and knowledge of CTAS rating system), a computerized system, eTRAIGE©, and expert panel, Dong (2005) concluded that a “fair” agreement was demonstrated with the memory triage process and the review panel selections; however, the evaluation of nurses using eTRAIGE© demonstrated “moderate” agreement. Figure 9 compares the triage scores of the three evaluating methods.

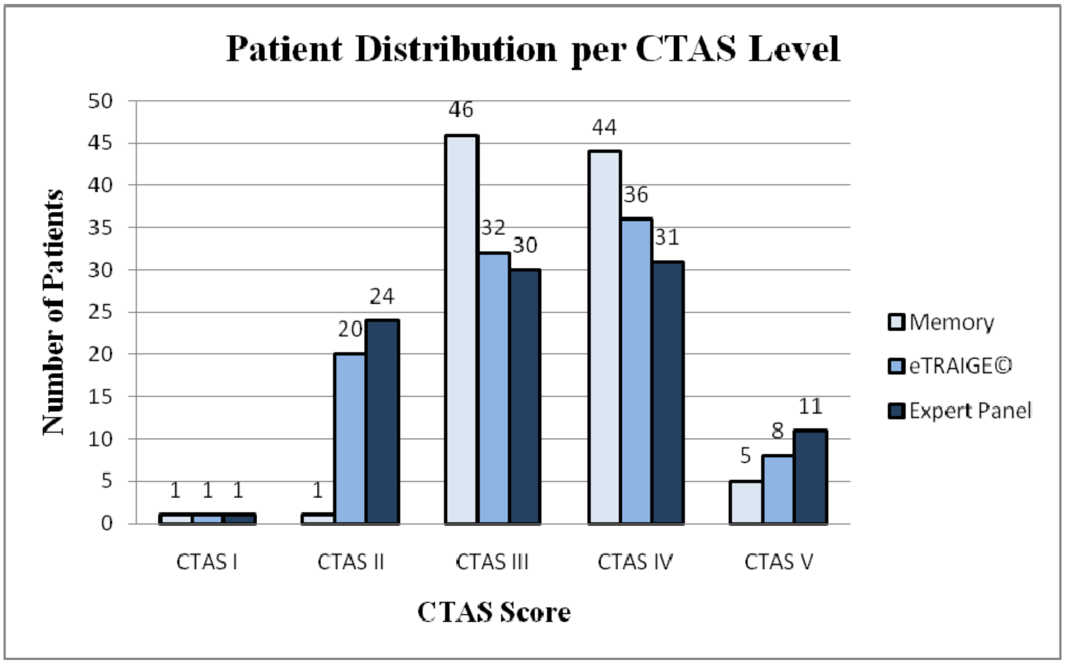


Figure 7 Patient in each triage category (Dong, 2005)

Dong (2005) reported in his study that four ED patients who were triaged as CTAS III and two triaged as CTAS IV died. Evidently those patients presented to the ED with conditions that deteriorated while waiting for treatment (Dong, 2005), or else, they were under-triaged.

2.4.3 Waiting for Initial Physician Assessments

The total amount of time spent in EDs, (i.e. LOS) consists of two time epochs: the initial time spent waiting to be examined by a physician after registration, and the time spent obtaining treatment for their illness until being discharged. The time spent to see a doctor is an important measure as it influences EDLOS. (Yoon, I. Steiner, 2003). Patients' outcomes are influenced by the time spent waiting for the initial physician assessment, which is an important factor for some specific medical conditions (M. J. Schull, 2005). In Ontario, according to The National Ambulatory Care Reporting System data, in 2003-2004 the median patient waiting time for physician assessment was 51 minutes; and 10% of patients waited 10 minutes or less (10th percentile); while 90th percentile represented 10% of patients who waited 165 minutes or more (Canadian Institute for Health

Information, 2005). In general, the volume of patients had limited effect in median wait times to see a physician while the patient severity level had much more effect (Canadian Institute for Health Information, 2005).

LOS in EDs can be examined by two time segments: the time from registration (or triage) to being seen by a physician and the time from then until discharge. Figure 8 represents ED LOS in Ontario's newly organized Local Health Integration Networks. Differences in ED LOS may in part be explained by differences in the distribution of illness severity of the patients seen in the Local Health Integration Networks (Canadian Institute for Health Information, 2005).

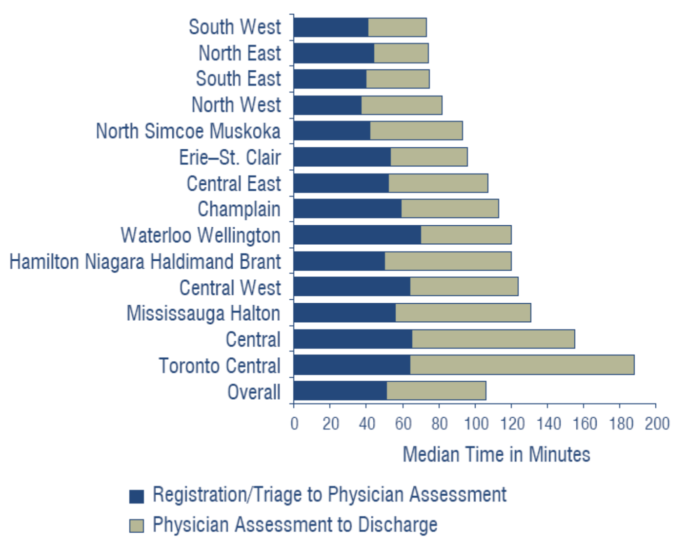


Figure 8 LOS in Local Health Integration Networks represented by two segments: the time from registration (or triage) to being seen by a physician and the time from the latter until discharge (Canadian Institute for Health Information, 2005).

How soon a patient sees a doctor is another measure of LOS in EDs. Statistics collected in 2003-2004 showed that patients could see a doctor more quickly if their registration or triage occurred between 7:00 a.m. and 9:00 a.m., despite the increase in patient volumes visiting EDs at this time. Increased number of staff coming on shift contributed to the quicker process time. Figure 10 illustrates the increase in patients' volumes while the time to see a doctor drops between 7:00 a.m. and 9:00 a.m. (x-axis represents the hourly day time of patient's arrival)

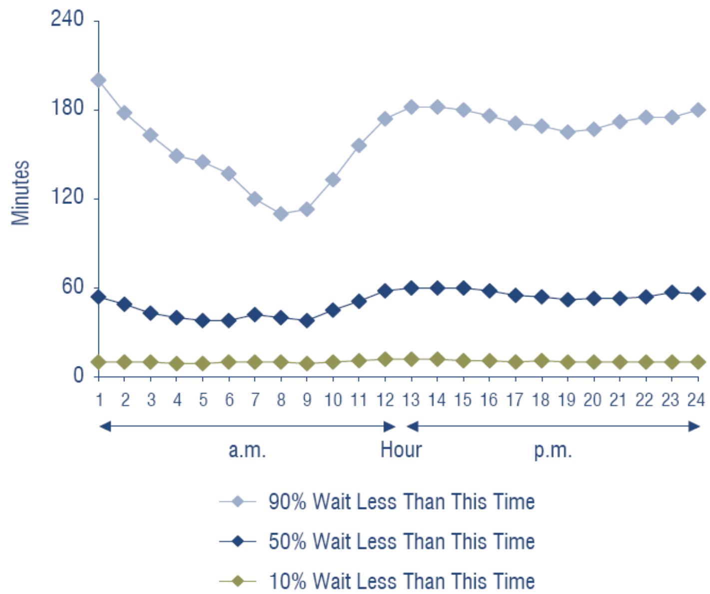


Figure 9 The time to see a doctor in ED (Canadian Institute for Health Information, 2005).

In general, in 2003-2004 half of the patients visiting EDs waited 51 minutes or less to be seen by a physician after being triaged. There seems to be a correlation between the time a patient waits to see a physician and the severity level. Figure 10 shows that the most severe level patients had the shortest waits, with a median of approximately five minutes for CTAS I triaged patients for instance; however, 10% of these patients were seen immediately (10th percentile = 0 minutes) whereas another 10% waited 45 minutes or more (90th percentile) (Canadian Institute for Health Information, 2005).

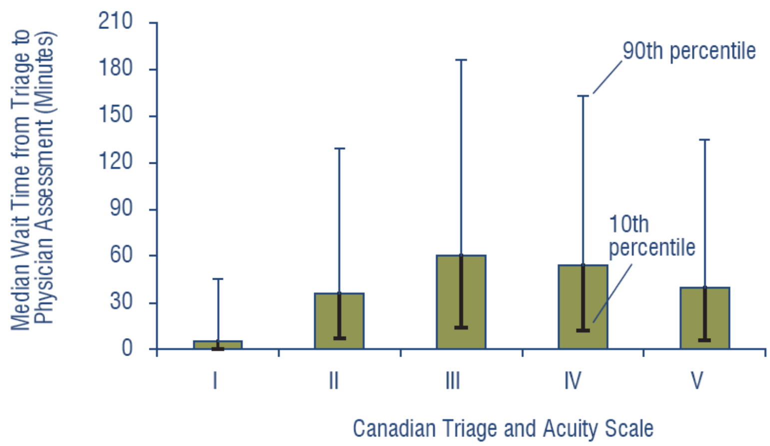


Figure 10 Median wait times for patients according to their triage level (Canadian Institute for Health Information, 2005).

Overall, high severe level patients (CTAS I, for example, shock, major trauma, cardiac arrest) had the shortest proportion of waiting time in EDs to be seen by a physician in 2003-2004. On the other hand, patients triaged as non-urgent (CTAS V, for example, sore throat, chronic back pain) spent the largest proportion of time waiting for a physician. Figure 11shows the proportional waiting time to see a physician according to CTAS severity levels (Canadian Institute for Health Information, 2005).

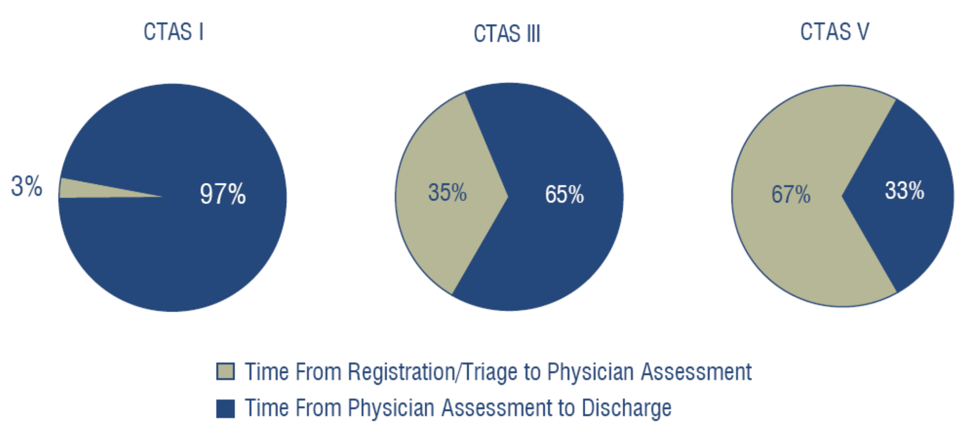


Figure 11 Proportional waiting times to see a physician according to CTAS severity levels (Canadian Institute for Health Information, 2005).

In November 2010, St. Paul's Hospital in Vancouver, BC established a pilot project that accomplished significant decrease in waiting times: waiting time to see a surgeon was reduced from 2 years to less than 4 weeks, while waiting time for surgery was cut down from 97 to 41 days. This reduction was achieved due many changes but mainly establishing screening and triage clinics consisted of six speciality trained GPs to examine patients and determine if a surgery was required. The project's success illustrates the need for decision-making stage to take place as early as possible in the process to eliminate waits associated with patients' triage and access to treatment (Mickleburgh, 2010).

In a study aimed at exploring which factors affect nurses' behaviour and moral evaluation in EDs, overcrowding, the unpredictable nature of patient's arrival, and increased percentages of non-urgent patients presented to ED seem to be the most influential; more specifically, nurses tend to treat non-urgent patients (who are the majority of ED patients) as intruders and abusers of the healthcare system (Grif, 1993).

Establishing Goals for Time to Physician Initial Assessment: Physician primary assessment is critical for patients in some cases, depending on the patients' conditions. Therefore, when the Canadian Triage and Acuity Scale (CTAS) was established, the following targeted times were established for a physician initial assessment:

CTAS I Resuscitation: immediate

CTAS II Emergent: 15 minutes

CTAS III Urgent: 30 minutes

CTAS IV Less-Urgent: 60 minutes

CTAS V Non-Urgent: 120 minutes

Even though the established times are not standards, they are useful as a baseline for comparison purposes between different EDs and for assessing performance. National Ambulatory Care Reporting System data analysis conducted in 2003-

2004 suggests that most patients are seen within these times. However it is not the case for everyone as a higher percentage of patients triaged CTAS V are examined by a physician within the proposed time (87% under 120 minutes) than patients triaged as CTAS I as 54% of those patients were examined in under 5 minutes. It is also observed that 10% of patients of this type waited 45 minutes or more (L. F. McCaig & Burt, 2002).

Limited resources in terms of space and/or staff impacts the time required to assess and treat patients. It is difficult to achieve the recommended time to treatment goals; however, improving ED LOS will enhance patient care and satisfaction (Marple, 2003).

Chapter III Proposed Methodology and Implementation

3.1 Statistical Analysis of ED Architectural Layouts

To investigate current trends and standards of designing EDs, 42 architectural designs were selected and analysed. The selection of EDs was based on the following criteria:

Inclusion criteria that define the type of subjects for the study:

- Demographic parameters: To ensure a degree of homogeneity in the sample, all sizes of annual ED visits were considered.
- Clinical characteristics: To narrow the sample to subjects appropriate to the study, only EDs at acute facilities were selected.
- Geographic considerations: over two thirds of the selected EDs are from Alberta, Canada. The majority of the selected EDs are located in an area accessible to the researchers. To ensure geographic diversity, nearly 30% of the selected EDs were located in the US and worldwide.
- Temporal setting: Prior knowledge and firsthand experience of the authors in either designing or investigating solutions for ED congestion issues was one of the criteria in the selection of EDs.

Exclusion criteria are as important as inclusion criteria because they help to predict and/or to eliminate potential study problems:

- ED layouts that provided poor quality data or unclear information were not selected.
- Accessibility to information that is essential to the analysis of ED layouts.
- Specialized EDs did not qualify for inclusion in the study (i.e. paediatric EDs).

- Probable confounding variables: hybrid ED processes that have no definitive usage of space and resources were not considered.

3.1.1 General Analysis

The geographical distribution of the selected EDs for the analysis was as follows:

- Canada 70.5% (n=30/42 EDs)
- US 19% (n=8/42 EDs)
- International 9.5% (n=4/42 EDs)

Analysis of the data collected from 42 ED architectural layouts shows that the overall distribution of ED areas is roughly 20% each in the ranges of 201-400 m^2, 401-600 m^2, and 1001-2000m^2, while the lowest representation (7%) of the ED area of less than 200 m^2. The distribution is depicted in Figure 12. The indicator that is worth considering is the distribution of clinical beds (i.e., examination, treatment, and observation beds) and trauma beds correlated with the emergency Department Gross Square Meter (dgsm) range. The distribution of trauma and clinical beds in the range between 201-400 m^2, which represents 24% of the total numbers of EDs examined, represents 12% of ED clinical beds. However, although the number of EDs with a range of 2001m^2 and greater represents only 14% of the total number of EDs, the contribution of this category is 33% of the total clinical beds in EDs. This is true for trauma bed distribution, with a percentage of 39%. It is evident that EDs with a smaller square footage range contribute less in bed count, for both clinical and trauma beds, due to the larger space consumed by supporting areas, as individual room sizes are almost the same regardless of the ED size. The average area per bed for EDs with a range size of 1001m^2 and greater is 48.6m^2; however, it is 61.5m^2 for EDs with a range size of 1000m^2 and less. The total average bed area of ED sizes is 54.87m^2, which is below the proposed standard[6] of 76.6m^2.

[6]Huddy, Jon (2006), "Emergency Department Design-A Practical Guide to Planning for the Future",*American College of Emergency Physicians*

The above mentioned analysis, as illustrated in Figure 12, presents a wake-up call for designers and decision-makers: the current practice of designing EDs is not in compliance with the existing minimum standards. Non-compliance to standards affects the quality of care and the patient-focused environment which are the goals of the healthcare delivery system. It also suggests that the most effective ED size is in the range of $1000m^2$ and greater, as this architectural design requires less area for supporting spaces per bed.

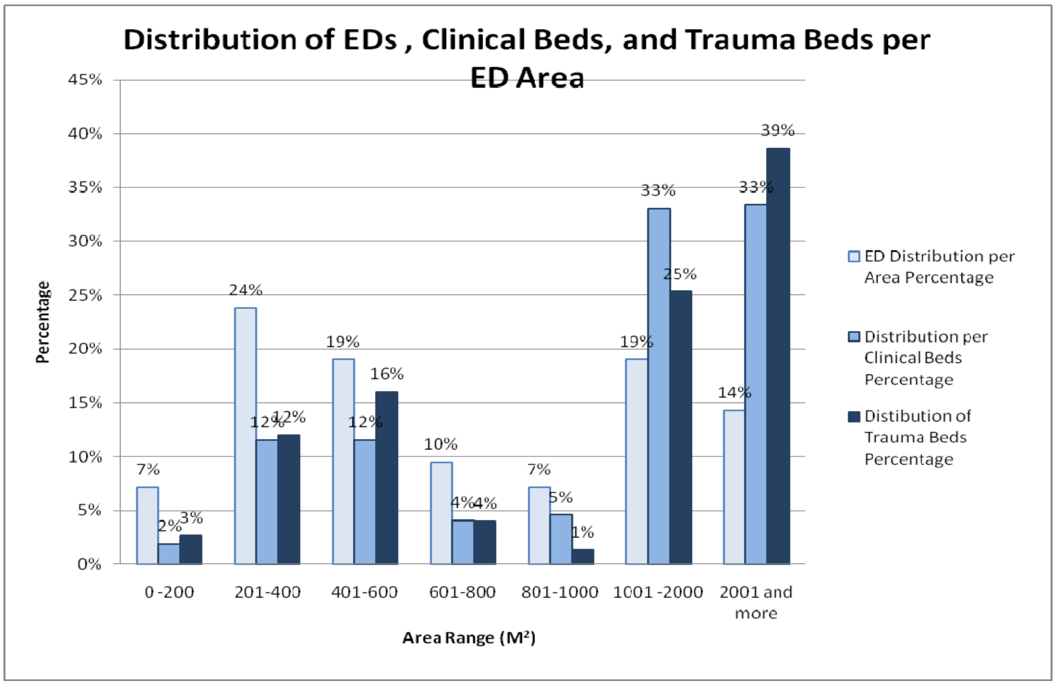


Figure 12 ED area distribution plotted against percentages of clinical and trauma beds.

Observed Current Functional Strategies to Reduce Waiting Time

1. Fast track is one of the strategies used to separate non-severely ill from severely ill patients. It is generally assumed that treating patients classified as CTAS IV & V in EDs is a major cause of congestion and lengthy wait

time; however, only 5% of the examined EDs have incorporated the fast track approach to solve excessive waiting time.

2. Examining and treating patients' illnesses depends on the ancillary departments which are one of the elements that affect waiting time in EDs. The statistical analysis of the examined ED layouts shows that:
   a. 10% have incorporated Diagnostic Imaging components within the ED.
   b. 12% have established a direct connection between the Diagnostic Imaging and the ED.
   c. 79% have a connection to Diagnostic Imaging through a corridor.
   d. 2% incorporated a pharmacy within the ED.

   The above mentioned numbers show that the current ED design practice ignores the effect of ancillary departments, specifically Diagnostic Imaging, that EDs depend on heavily in their processes.

3. The statistical analysis shows that 14 % of EDs have established a specialist to recognize, early in the process, psychiatric or mentally ill patients and provide the appropriate intervention methods; recognizing and dealing with psychiatric or mentally ill patients is one of the challenges to move patients smoothly through the ED process.

Observed Current Architectural Design Strategies

The Standard Patient Treatment Room: Healthcare facilities are highly functional, driven buildings. The design should conform to how the building should function; the function should not conform to the design. In EDs, treatment or examination rooms are the key areas of treating patients. While standards specify minimum space requirements, adhering to those minimums will affect the flow in EDs as improved processes require improved area standards. The old process compared to the new approach is explained in Table 1, with its effect on room sizes as specified in the code.

Table 1 Design change of ED treatment rooms that conform to function.

Existing Approach	**New Approach**
Linear process in examining and treating patients (first the nurse, then the doctor).	Multidisciplinary team approach with several caregivers attending to the patient at the same time.* (Huddy, 2006).
Patient room size is 9.3 -11.2 m^2 (100-120 sf.) **(code minimum standard).	Patient room size that is 13.9 – 14.9 m^2 (150-160 sf) allows for access to all sides of bed including the head.***
The number and size of equipment used in the design is not to today's standards (bed side computers and respirator machines).	The number and size of equipment have increased in the last 30 years.

*The team approach requires a larger patient care space.

** Code minimum standard (The Facility Guidelines Institute, 2010).

*** Comparison results of Figure 12.

ED patient care areas are usually designated for different levels of care, non-urgent or fast track, and observation/evaluation/clinical decision spaces. It is crucial to be able to designate any unit of the ED for any level of patient care. Eliminating inadequate treatment spaces for levels of care that are not intended for those spaces is an important factor that reduces wait and designs EDs as patient focused-environments. Figure 13 and Figure 15 show the design of a treatment room, as per code minimum standard, for both single and double-bed rooms. This is not recommended for the new approach, as it slows down the process for two reasons: first, rooms are usually too small and crowded; second, it lacks identical designs. If each room has the same design, with medical appliances located in similar locations, practice is faster and less error-prone; professionals do not waste time locating medical appliances.

Figure 13 A typical design of a 12.3 m^2 treatment room.

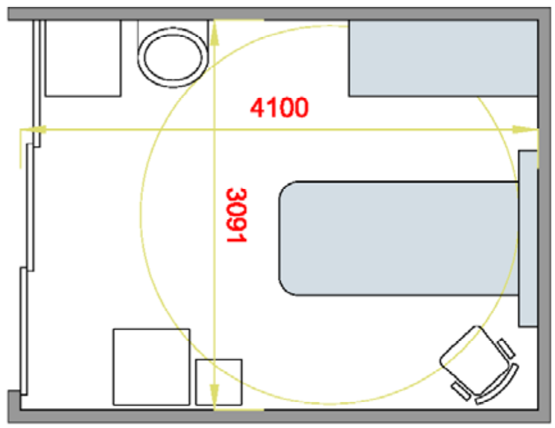


Figure 14 Design of a private examination room that shows the acceptable minimum of 13.8 m^2.

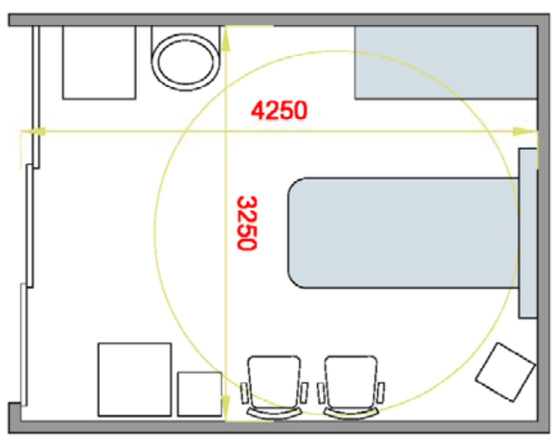
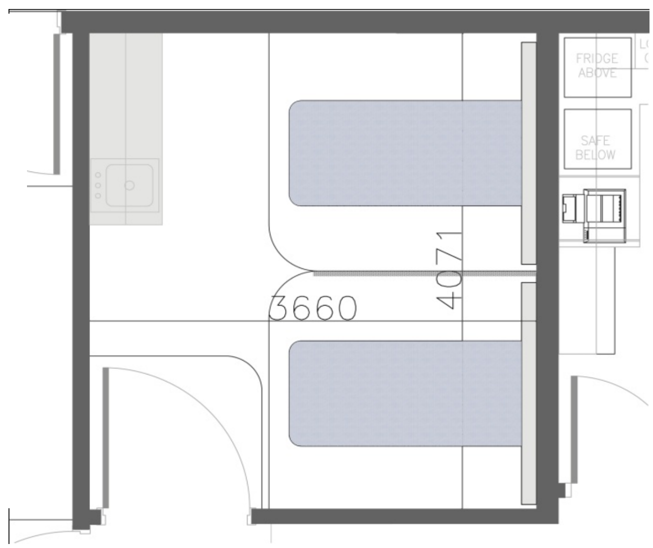


Figure 15 A typical design of a double room 14.64 m^2 shared spaces.



A non-effective approach to excessive waiting time occurs when healthcare providers try to accommodate more beds within EDs using curtain separation; Approximately 25% of EDs implemented curtain separation in examination and treatment spaces; this design requires less space per bed at the expense of patient privacy, as shown in Figure 14.

Adopting identical examination room design allows faster processing and eliminates errors, as professionals do not have to look for medical tools or operate medical appliances; Figure 18 illustrates the identical architectural design of examination rooms.

Figure 16 ımplementing curtain separation in a typical examination and treatment spaces.

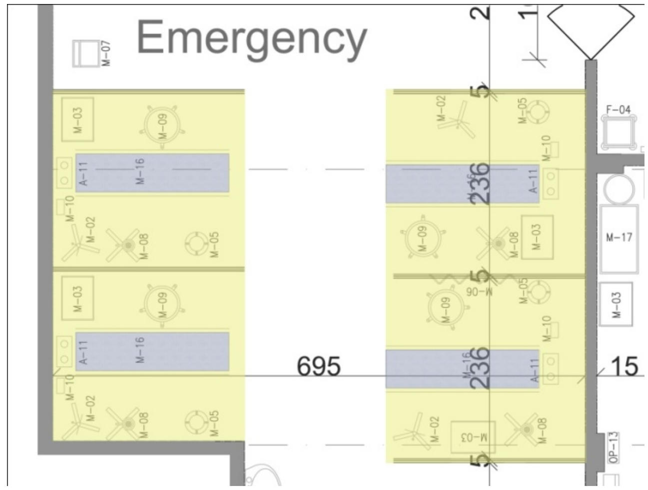
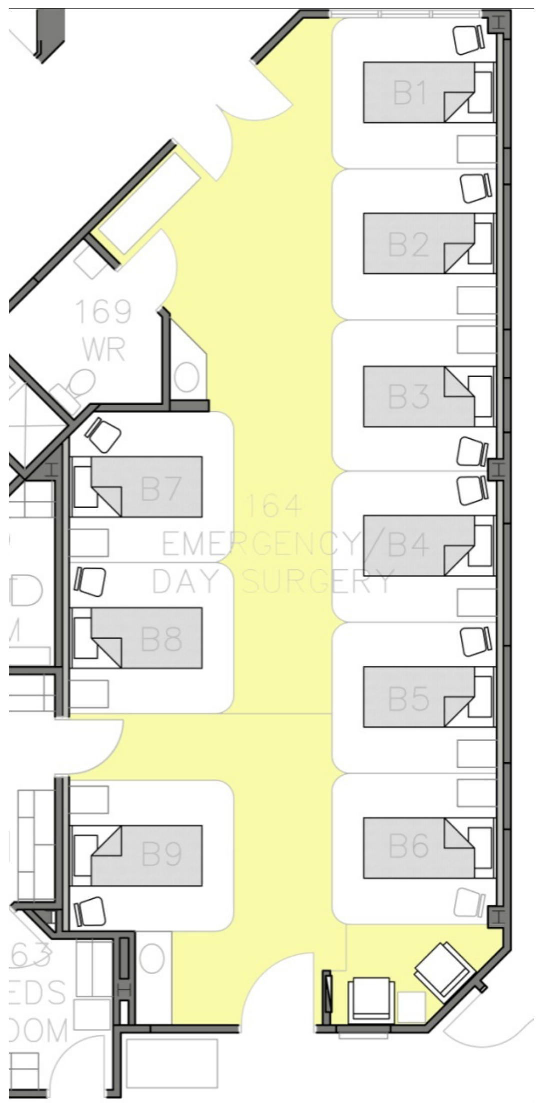


Figure 17 The curtain separation approach of typical ED examination rooms.



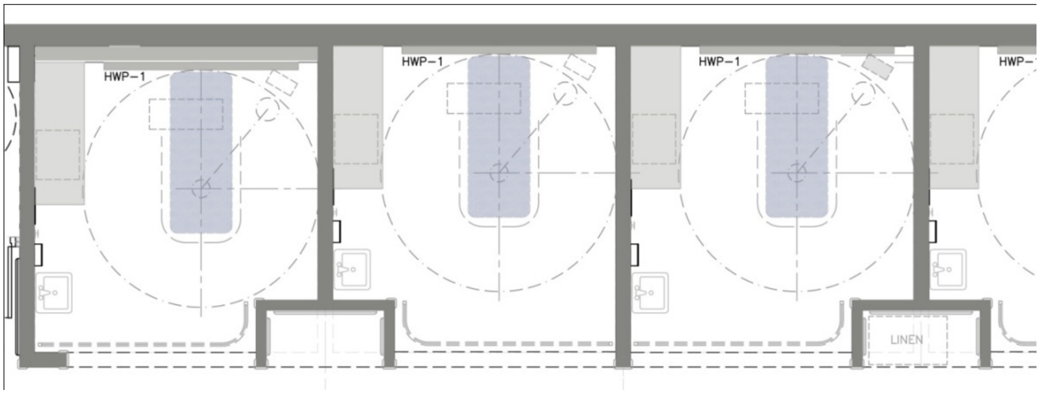


Figure 18 Identical examination room design.

Observation Rooms: Some hospitals have observation areas that serve two purposes: a) a space for patients who are waiting for inpatient beds, and b) observation spaces for patients held for observation, evaluation, or clinical decision; these can be integrated and used 24/7 as an observation and examination rooms as well; the integrated model will replace the linear process which in turn improves throughput in EDs. Figure 19 shows an ED layout that incorporates the integrated model.

Figure 19 An ED layout that incorporates observation areas, patient holding and/or clinical decisions.

Sharing Resources: Predicting the type of care and number of patients visiting an ED at any given time is almost impossible. Observation of the common practice of designing and operating EDs reveal the following two characteristics:

- Architectural layouts show that EDs have separate modules, designated for emergent, urgent, and non-urgent care, or for evaluation, paediatrics, psychiatry, etc.
- The number of physicians and nurses are specified according to the designated ED modules regardless of the number of patients occupying those modules.

Based on the two afore mentioned observations, this practice hinders the department's ability to share efficiently its human and physical resources, and leads to more expensive operations as it requires more resources. A recommendation which promotes more flexibility in using both the physical and human resources of EDs would ensure that any department space could be used for any patient care type. Operationally, the design should allow for sharing staff and other resources efficiently, and promote a team approach as an operational model. Figure 20 illustrates the segregation of Trauma rooms that should be clustered within Examination rooms.

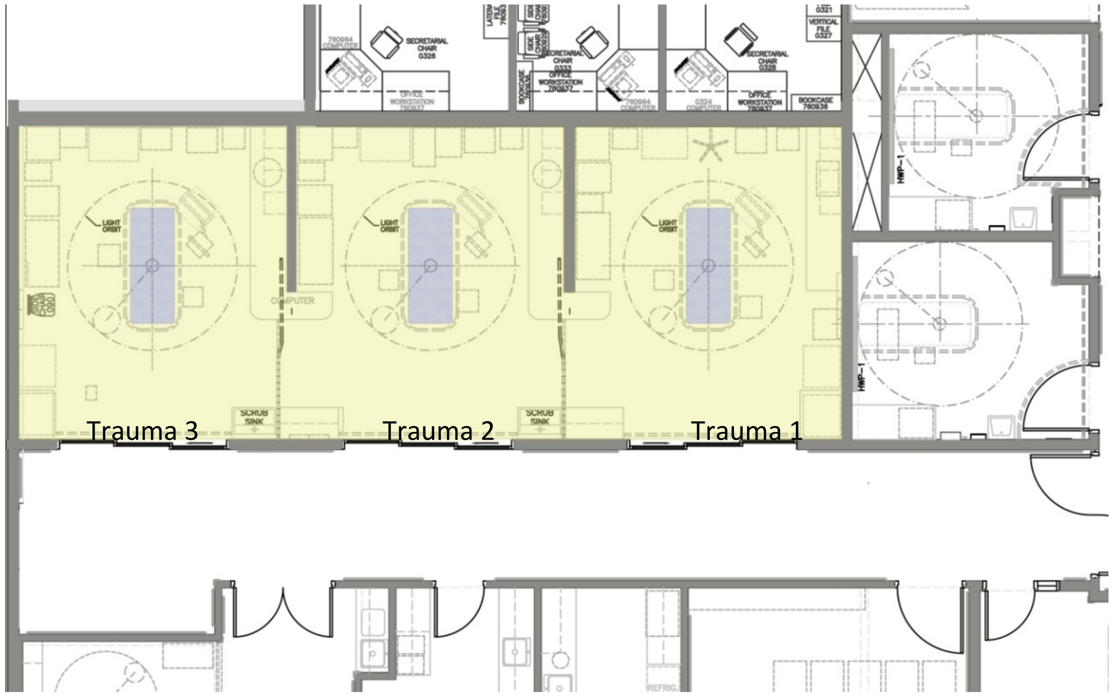


Figure 20 A typical design of segregated trauma rooms from the rest of the ED components

3.2 Process Design Change and Principles

ED design is driven towards fixed objectives determined by healthcare professionals rather than designers, such as capacity, a professional-focused environment, security, and budget. In this section, the principles that enhance ED process and design are presented.

3.2.1 Patient-focused Environment Principles:

Medical professionals or users are usually involved in designing EDs, determining process requirements, and selecting equipment. As such, they are considered the process owners. However, the only person who experiences the process in the ED from admission to discharge is the patient. It is crucial in this sense to add patients to a user-friendly concept that focuses more on patients' needs, rather than professionals'. Although some patients are revisiting the ED, for most people, a visit to the ED is a first. Patients are often worried, confused, sick, and unaccustomed to the ED environment. The systems and space must be patient-friendly and responsive to first-visit patients and follow the following criteria:

- Short waiting time
- Positive patient experience
- Advanced level of care
- Easy process flow and way-finding
- Patients do not repeatedly explain their symptoms in different stages to different caregivers while in ED

Operational Goals vs. Design Goals: The complexity of and difficulty in improving the ED process in relation to architectural design lies in transferring operational goals that are sometimes too abstract to measure into physical design goals that affect operational outcomes. This research aims to achieve the following:

- Have all patients seen in a timely manner
- Develop system improvement that supports reduced time of admission
- Reduce the number of LWBS cases
- Reduce waiting time, ideally for both patients and staff
- Improve access and communication with attending physicians and ancillary departments
- Reduce LOS
- Improve processing efficiency
- Improve the work environment and reduce frustration for both patients and healthcare providers while providing care to patients
- Focus on patient-based design to enhance their experience while in ED
- Eliminate waste in all its forms.

3.2.2 ED Process Design

Architectural Design Scheme of ED

The ED design scheme, known architecturally as the "Funnel Design Scheme," has many bottlenecks due to a linear process design that makes every stage in treating patients dependent on the previous one. This design scheme results in a long waiting time as the current architectural practice and standards do not apply tools or principles to quantify the effect of design on patients' waiting time and LOS in the ED. On the other hand, the linear process in the ED depends on ancillary departments to provide services that are an important part of treating patients, either reducing or increasing the speed of flow within EDs.

Design Concept in Patient Care Areas

Current Practice Triage Process: The current practice of patient treatment in EDs - as observed in 41 of the 42 examined EDs - requires a patient to see a triage registered nurse first, who performs an evaluation using computer software. Depending on which of the five severity levels the software suggests, a non-critically ill patient of CTAS III, IV and V would move forward to the registration desk, and after the registration process the patient would go to the waiting room. Meanwhile, a patient chart is prepared and placed in the incoming chart rack for pick-up by medical staff when an examination and treatment room becomes available. The other levels of severity, CTAS I and II, involve the same process with the exception that urgent care patients are given priority over non-urgent patients. Emergent patients of CTAS I, the highest severity level, are admitted immediately to an examination room as their illness could be life-threatening.

Proposed Triage Process Design Change: The research approach to patients' triage is based on the concept that triage in the current practice is not a "decision-making" stage - which is ignored in the 42 examined EDs - (refer to Chapter II. Section 2.2.3) which leads to overloading the system with approximately 57% (as shown in Figure 11) non-urgent care levels of CTAS IV & V patients who wait for longer than Canadian standards allow. Triage is eliminated in this approach, and patients arriving in the ED can be briefly assessed by a nurse and then fast forwarded to an examination room regardless of the severity of their illness. In the examination and treatment room, the patient can be seen without delay by a physician and a nurse for examination and treatment, and further examination and tests are scheduled if needed. Registration can be performed by medical staff, also known as bed side registration, at any time when the patient is not undergoing tests or treatment. Figure 21 illustrates the proposed streamlined process of an ED.

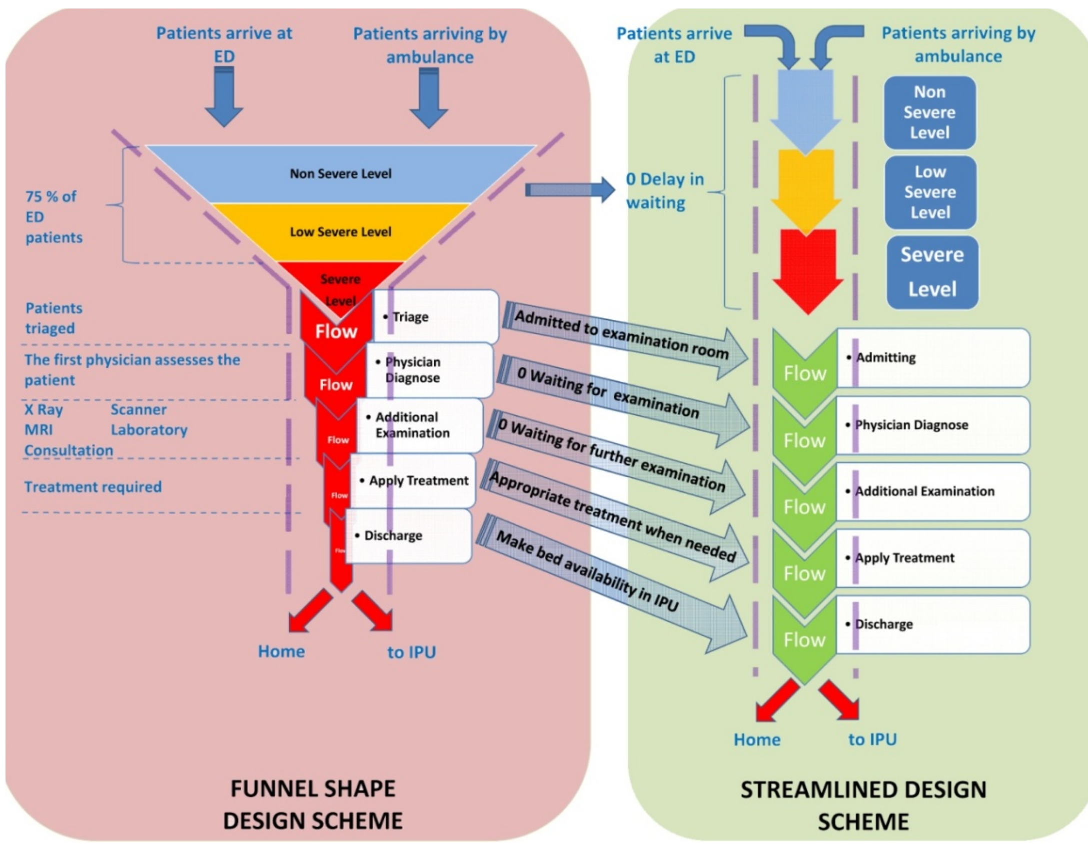


Figure 21 The current Funnel Shape Design Scheme and the proposed Streamlined Design Scheme processes of ED.

Ancillary Departments: The Surgical Department, Diagnostic Imaging, and Labrotary are major ancillary departments on which the ED depends to diagnose and treat patients. As illustrated in Chapter II, Section 2.3.1, these departments affect the process flow when they do not provide the needed services in a timely or effective manner. To eliminate the negative effect of the ancillary departments on the ED process, the following two methods are proposed:

- The ED can host X-Ray and CT-scan services within the department, which will eliminate competition with the hospital for Diagnostic Imaging resources. The same approach applies to Laboratory or Pharmacy services. It was observed that only 15% of the examined architectural design layouts (Section 3.1.1) have implemented this approach.
- Another mitigating method is to create a schedule that blocks both physical and human resources within Diagnostic Imaging, Laboratory, Pharmacy, and ORs for the servicing of ED patients.

Patient Discharge: Another factor that affects ED efficiency involves discharging patients who can free ED beds and stretchers. Patients ready to be discharged from the ED either go home or are admitted to the hospital's Inpatient Unit. Discharging patients to their home is usually a smooth process; however, discharging patients to the Inpatient Unit is not typically an easy process as patients have to wait for hospital bed placement due to the reasons described in Chapter II, Section 2.3.1. Mitigating these issues could involve the following:

- Establishing holding areas for patients waiting to be admitted to the Inpatient Unit, and creating physical space that can also be used for other functions.
- A good tracking system that enables ED professionals to transfer patients to available beds in different facilities across the city.
- To guarantee an easy discharge of ED patients, hospital beds should be freed more frequently, or enough beds should be provided for admitted ED patients.

3.3 Implementation Techniques and Case Study

Functional processes within the ED are complex and changes cannot be made easily in real life situations as it can be costly and may compromise patient safety. Computer modeling of both existing and proposed processes provides the opportunity to examine and test the possible changes. As illustrated in Figure 21, the research focuses on the following decision-making tools that help determine the value proposition of process design change: Lean Healthcare combined with VSM simulation, and post-lean DES that evaluates the potential impact of different interventions on patient flow and throughput, and physical design or staff resources.

3.3.1 Implementation Techniques

As illustrated in Chapter II, researchers have proposed methods that coordinate ED census and drivers of congestion with ED patient overflow and functional processes; however, this research approach proposes an additional layer to the afore mentioned methods which includes the examination of ED architectural designs and statistical analysis of ED design components. The variability of ED patient admission and LOS affects waiting time, and a decrease in this variability would improve ED output and subsequently ED waiting time. This research reinforces these concepts by showing a correlation between LOS and waiting time as illustrated in Chapter II, Section 2.4.3. All of the afore mentioned strategies would decrease the amount of time patients spend waiting to be admitted in the ED, reduce ED LOS, and free ED bed space to treat new patients.

By modeling the ED process through computer simulation, the research shows that improving ED design and challenging current practice standards improves ED LOS and therefore waiting time. Figure 22 illustrates the proposed methodology of implementation techniques.

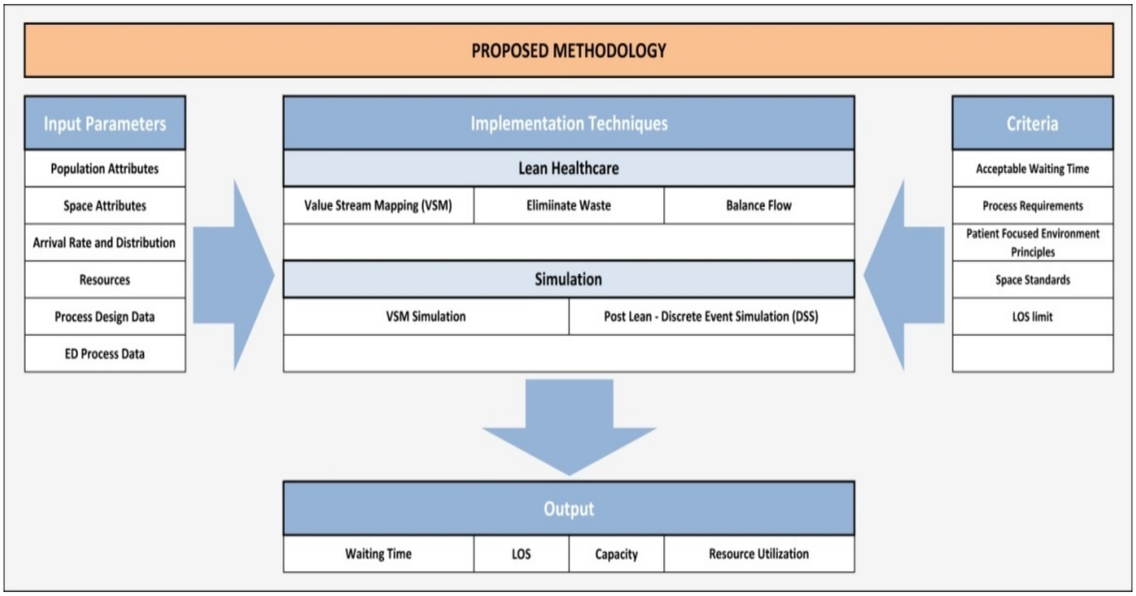


Figure 22 Proposed methodology of implementation techniques.

Lean Healthcare Implementation: Lean Healthcare, which uses the same principles of lean manufacturing adopted from the Toyota Production System, is a cornerstone for operations management research. One of the measurements of Toyota Production System, known as Takt time, determines the demand frequency, and in this case, how frequently the ED serves patients. It can be calculated as follows:

Takt = Daily operating time/Required quantity per day **(Equation 1)**

Takt time also allows for understanding the process conditions and attributes momentary, and to identify and eliminate the root cause of a problem, if any exist.

Lean Healthcare Process Modeling allows understanding of how patients are served currently and in the future. It also identifies inefficiencies, miscommunication, and inconsistencies in applying treatment methods. The emphasis on evidence-based decision-making measures guarantees that performance and patient satisfaction indicators are monitored and integrated into a continually improving system. Fundamental enhancements in ED process design are currently feasible when used to their maximum capacity. Value stream mapping is applied in two cases, the current state of the existing practice and the future state, in which changes are modeled and applied to ED functional process and design.

Post-Lean Simulation Implementation

Post-lean Simulation helps evaluate the "before and after " processes in the ED using a structured model. Each component presents new challenges that require detailed analysis to ensure all aspects of ED are adequately addressed. The objective is to develop a realistic ED simulation model with the capability of analyzing operational alternatives and best practices and determining their associated value propositions. Below is an outline of the basic methodology of simulation modeling:

1. Identification of ED components that includes process mapping, as well as understanding of the process, research scope, requirements and data availability.
2. Development of a functional specification of process descriptions, modeling assumptions, input and output data definitions and planned scenarios.
3. As the model development begins, data analysis, and detailed draft process flows of the current operations would be developed.
4. Once the model has been developed, a verification step is performed.
5. Once verified, the model is validated. Medical professionals are involved to make sure the model accurately reflects the system under analysis.
6. An initial simulation run is conducted. The model output becomes the baseline result.
7. The detailed process model of ED processes identifies resource bottlenecks.

8. Future state maps and industry best practices will be identified and scenarios implemented either by data interface updates or by model logic changes.
9. All modeling efforts are summarized.

Input Parameters

Input parameters that are specific to EDs are examined and prepared for each of the tools, such as population characteristics, space attributes, arrival rate and distribution for different times and types of patients, resources available, and the specific sequence of ED functional process stages. Two factors are considered in modeling the system input: ED capacity and the distribution that represents the input data.

Criteria

The application of the above mentioned decision-making tools requires criteria for evaluating results and the limits of each application. These criteria include acceptable waiting time limits, process specific requirements, patient-focused environment principles, space standards, and LOS acceptable limits. One criterion that measures the quality of service is the delay in patients' care. Delay can be examined at each stage of the ED process and categorized in three major phases:

- Delay between arrival at registration desk or triage and the time seen by a physician for initial assessment.
- Delay between first seeing a doctor and being discharged.
- Delay between ordering tests (or Laboratory/ pharmacy, etc.) or further examination by a specialist and resuming further treatment, if any.

Output

The expected output will be the result of applying the implementation techniques using the input parameters within the criteria's controlled limits. Waiting time and LOS are determined for the new process design; usage of both human resources and physical space, and capacity for both ED as a whole and its individual departments are examined.

3.3.2 Case Study

This research builds on data obtained from a case study at Hôtel-Dieu Grace Hospital in Windsor - Ontario, Canada. In this case, the ED receives 60,000 patients annually, and has many issues that are common among big city hospitals: long wait times, low morale, high employee turnover, patients leaving without being seen, and angry patients and families that require increased security (Taninecz, 2007). The methodological approach to this research's case study is illustrated in Figure 23 and focuses on:

1) ED problems and challenges: Reviewing the operational procedures and identifying bottlenecks and redundancies.
2) Design standards and process requirements: Classifying information that is provided by healthcare professionals, codes and design experts. This step has been explored in the previous sections.
3) Skills and Resources: Different healthcare scenarios require different resources and techniques.
4) New or streamlined working methods: Streamlining methods may have an effect on the physical environment.
5) Implementation methods: Lean Healthcare application, modeling and simulation methods and their requisite skills and resources ensure that the updated ED process does not support the traditional, inefficient operational process. The application of decision-making tools helps arrive at new design standards based on proposed and tested ED processes.

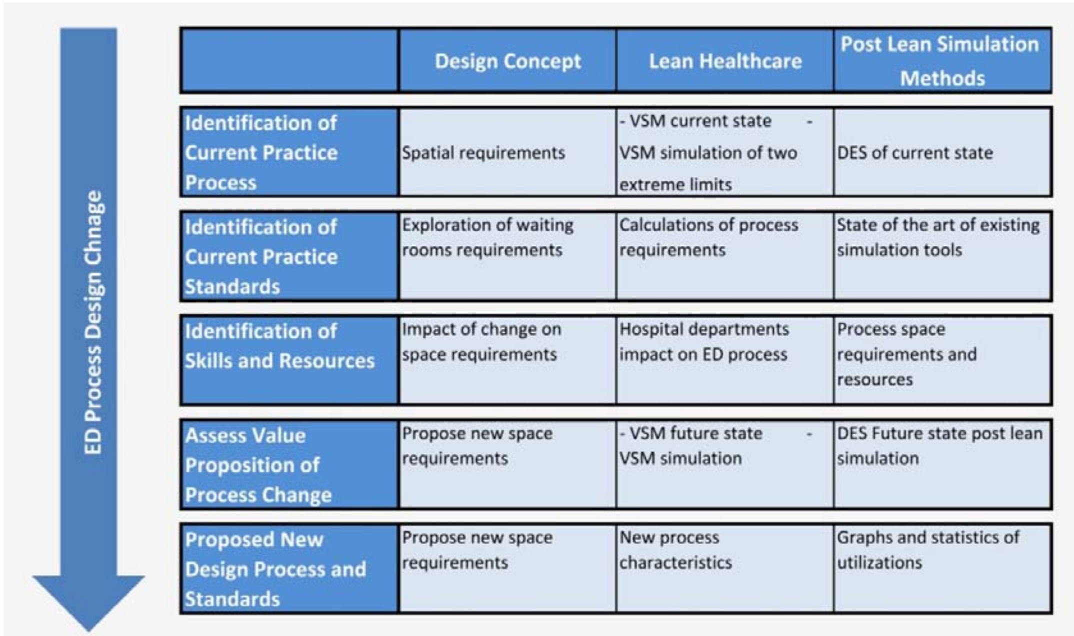


Figure 23 Implementation and research methodology.

Mapping ED Process for the Current State

The ED Process Value Stream Map (VSM) for a high severe level of patient acuity is shown in Figure 24, and for a low severe case in Figure 25. Table 2 shows the activities and their associated times represented in triangular distribution, as well as the medical professional who is responsible for conducting the prescribed activities. The mode C of triangular distribution has two values: Low represents the low severity level of patient acuity and High represents high severity. Between the main process stages, wait time is indicated in two forms: wait for treatment and wait in queue. It is important to differentiate between two types: wait which is not considered waste, such as waiting for recovery from treatment, and wait that is considered waste, that which does not add value to the treatment process.

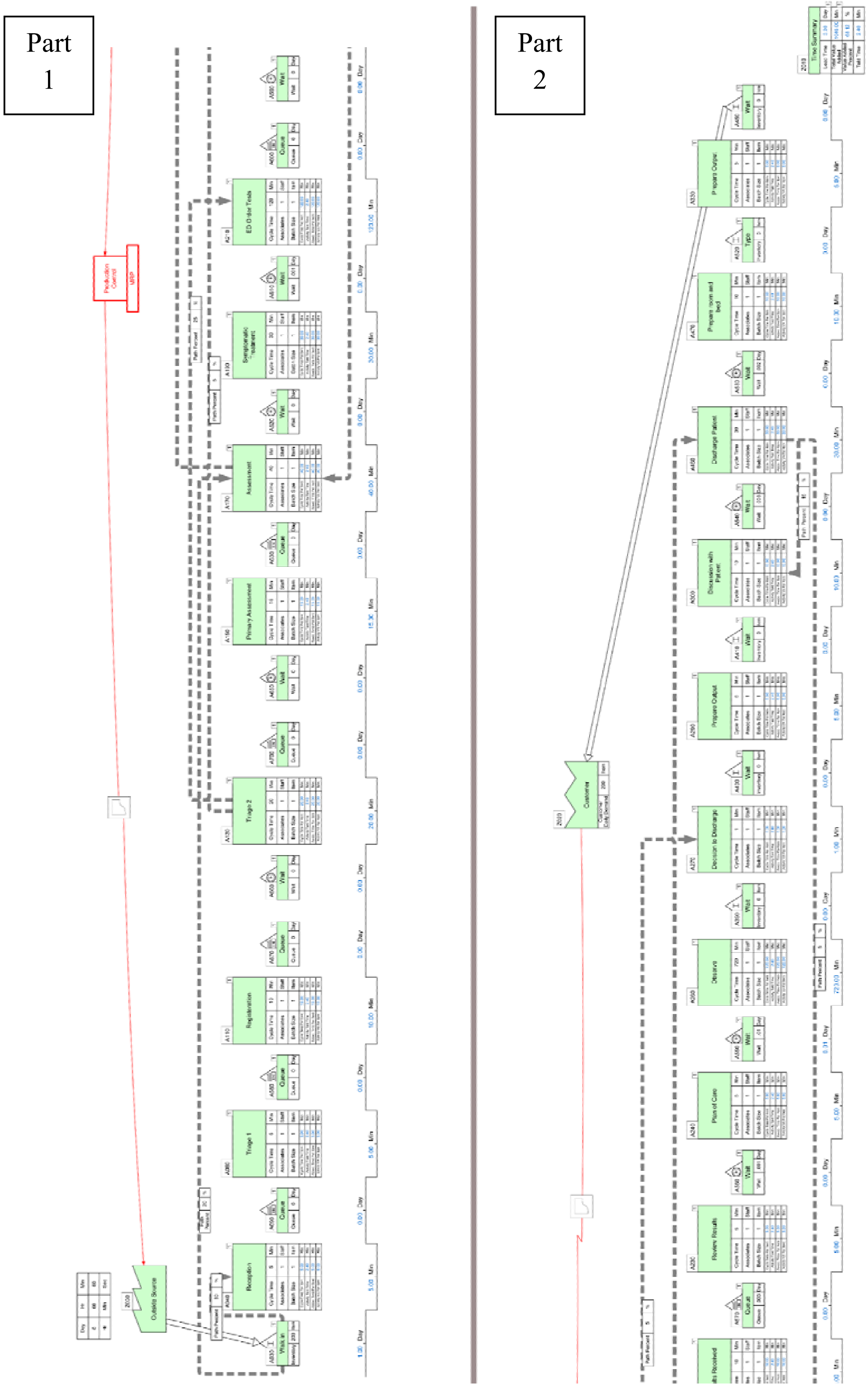


Figure 24 Current state map of high severe level patient's process.

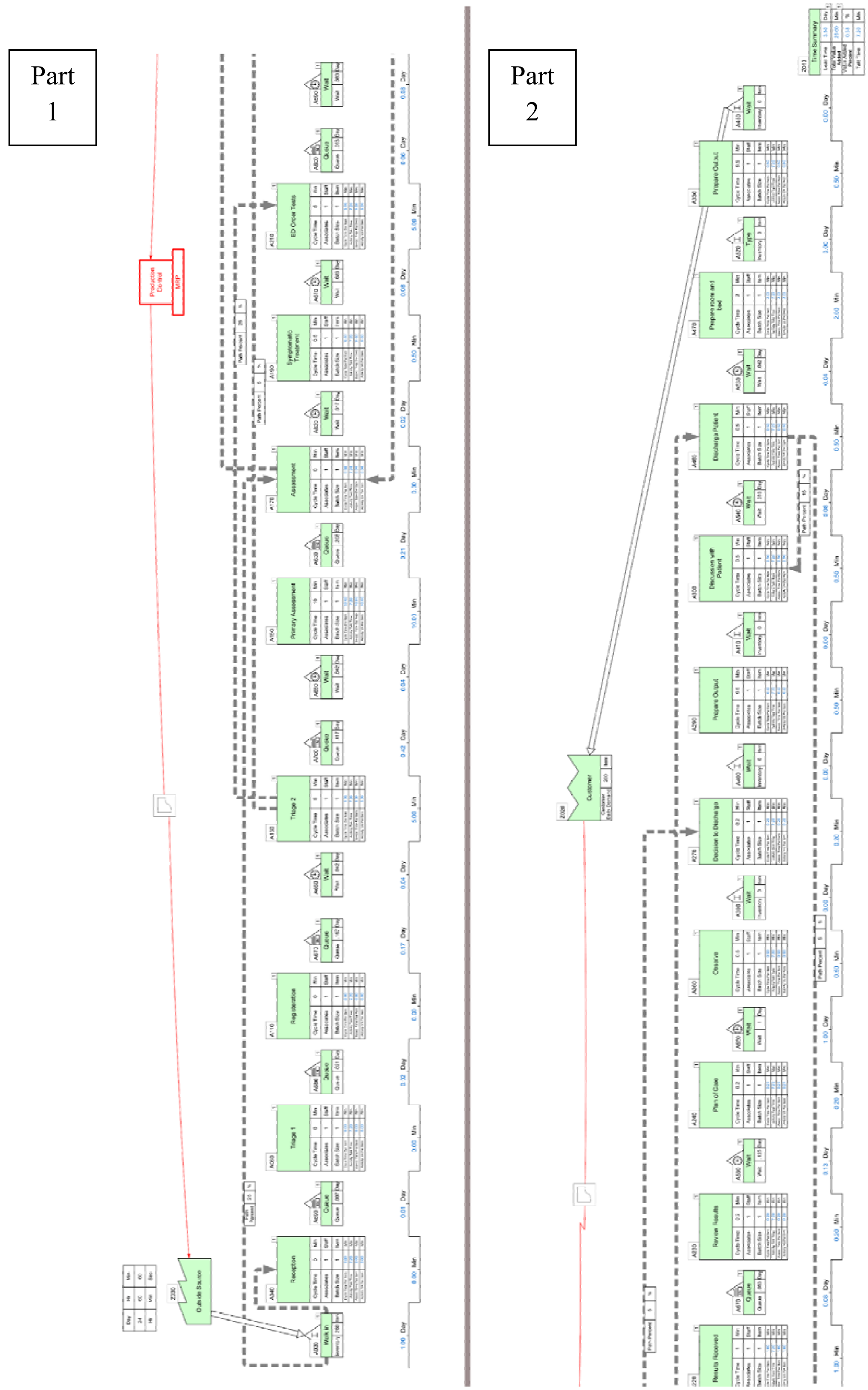


Figure 25 Current state map of Low severe level patient process.

Table 2 ED current state process times and resources of Hôtel-Dieu Grace Hospital in Windsor, Ontario.

Activity #	Perfromed By	Activity	a	c (mode)* Low	c (mode)* High	b
		Current State Processes				
1	Clerk	**Reception**	0.1	2.6		5
		Queue	0.1	5.05		10
2	N	**Triage 1**	0.3	0.7		1
		Queue	0.1	15.1		30
3	Clerk	**Registration**	0.5	5.3		10
		Wait	0.5	30.3		60
		Queue	0.5	120.3		240
4	RN	**Triage 2**	5	8.8	16.3	20
		Wait	0.5	15.4	45.1	60
		Queue	0.5	150.4	450.1	600
5	RN	**Primary Assessment**	10	11.3	13.8	15
		Queue	0.5	75.4	225.1	300
6	MD	**Assessment**	0	22.5	67.5	90
		Wait	0.5	12.8		25
7	N	**Symptomatic Treatment**	0.5	7.9	22.6	30
		Wait	1	60.5		120
8	MD	**Order Lab / DI Test(s)**	5	33.8	91.3	120
		Wait	0.5	60.3		120
		Queue	0.5	22.9		90
9	N	**Test Results Received**	1	2.5	5.5	7
		Queue	0.5	60.3		120
10	MD	**Review Results**	0.2	1.4	3.8	5
		Wait	1	90.5		180
11	MD	**Plan of Care**	0.2	1.4	3.8	5
		Wait	15	727.5		1440
12	N	**Observation**	0.5	180.4	540.1	720
13	MD	**Decision to Discharge**	0.2	0.4	0.8	1
14	MD	**Prepare Output**	0.5	1.6	3.9	5
15	MD	**Discussion with Patient**	0.5	7.9	22.6	30
		Wait	5	33.8	91.3	120
16	N	**Discharge Patient**	0.5	7.9	22.6	30
		Wait	2	31.0		60
17	HK	**Prepare Room and Bed**	2	4.0	8.0	10
18	HK	**Prepare Output**	0.5	1.6	3.9	5
19	MD	**Follow-up Call Backs**				

Time Distribution (Triangular)/min

Abreviations

- N — Nurse
- RN — Registered Nurse
- MD — Medical Director
- HK — House Keeping

* Mode presented for Low/High when Severity of illness level has an effect

** Number of Patients arriving per day is assumed 200 patients

Value stream simulation was produced using eVSM software, Version 5.20. Simulation was performed for two extreme scenarios following patient processes with a low severe level, output data collected from simulating high severe level patient's process is shown in Appendix D; and another run with data of a high severe level process, output data collected from simulating low severe level patient's process is shown in Appendix E. In both cases, the purpose was to investigate the bottlenecks and where the process was congested. For the High severe level, the model indicates that the bottleneck is in the Observation stages (with a value of 700 minutes), and to a lesser extent in Ordering Tests for Diagnostic Imaging and the Laboratory, as seen in Figure 26. For the Low severe level, the model shows congestions in Triage, Primary Assessment (with a value of 10 minutes) and Ordering Tests, as seen in Figure 27. It is worth mentioning that Takt time is 7 minutes for both processes:

As per equation (1): Takt= (24*60)/200 = 7 minutes

Another element that was extracted from the model is the value added (or the Non-value added) percentages. In the High severe level, the time of the value added tasks is 68% of the total time, while in the Low severe level it is 52%. Clearly, the Low severe level process is not as efficient as the High severe level; however, both processes are not completely efficient, as the wait is considered to be waste. Figure 28 and Figure 29 illustrate the non-value added timeline of High and Low severe level patient process respectively.

Mapping the current processes showed the complexity of the ED queuing network, which is affected by many factors. These factors minimize patient queuing or cause considerable delays depending on the patient flow effectiveness. In general, factors that affect patient flow can be summarized as:

- Coordination between the work stations that provide care and service to patients.
- System supervising management that allows constant monitoring.
- Time management and resource availability.

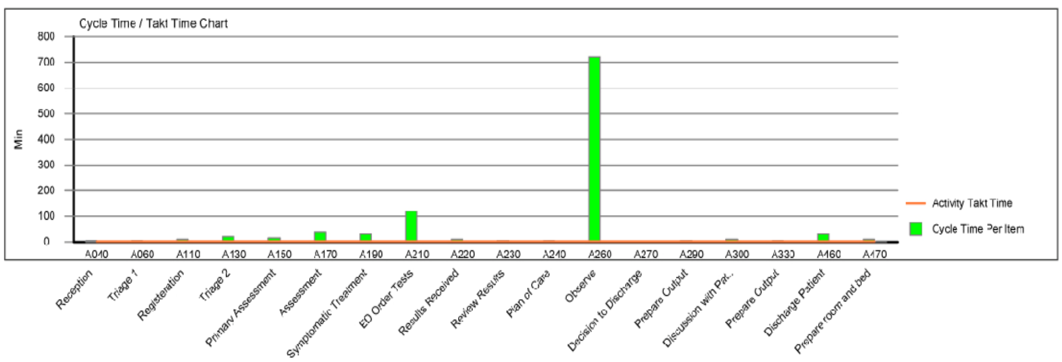


Figure 26 Cycle times of High severe level patient process.

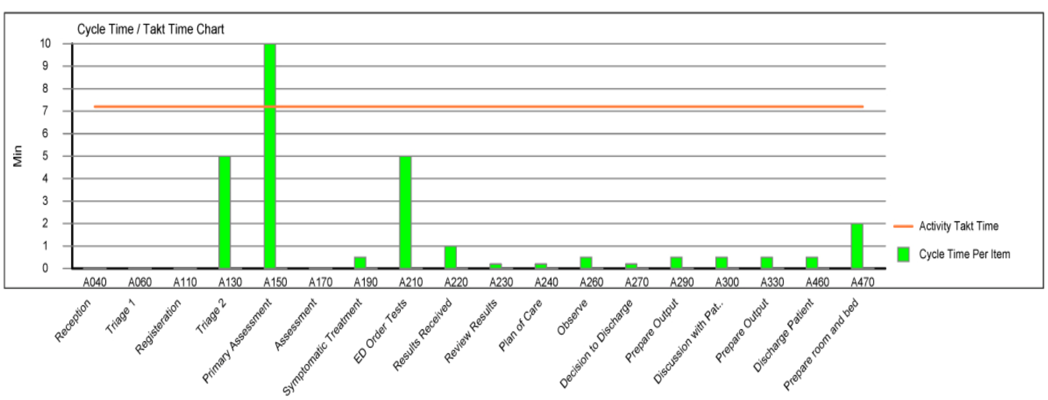


Figure 27 Cycle times of Low severe level patient process.

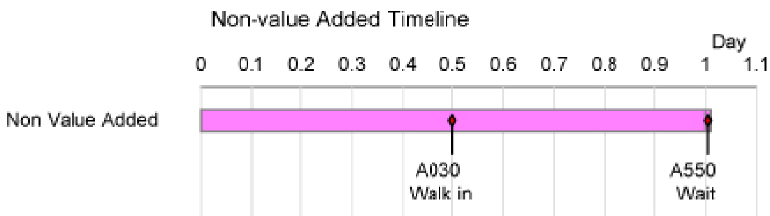


Figure 28 Non-value added Timeline of High severe level patient process.

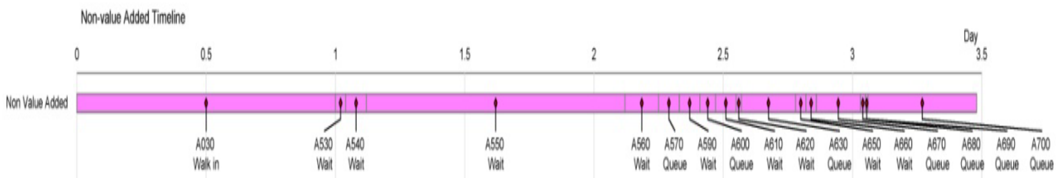


Figure 29 Non-value added Timeline of Low severe level patient process.

Process Change and Characteristics

ED processes can be categorized into two types of Lean pull systems[7]:

Type 1: Consists of CTAS IV & V patient types with high volumes and short and stable lead times. This type requires queues between processes. The pacemaker is the last process in the system, which involves discharging patients either home or to the Inpatient Unit. The challenge is to enhance the capability of moving patients from one stage to another to minimize queue length.

Type 2: Consists of CTAS I, II & III patient types, as frequency is lower and patient lead time is longer. The pacemaker stage is at the first point of initial examination when patients are admitted to examination rooms. Patients move in downstream processes, proceeding one after another through the "first in, first out" (FIFO) sequence. Unlike the Type 1 process, and due to the low number of patients, no lengthy queues are examined. It is important to establish a system that can accommodate both types of processes.

Post-Lean Simulation

Discrete Event Simulation can model many departmental functions in a healthcare facility. In the building planning and design phase, collaboration between architects, healthcare planners, simulation models, doctors, nurses and patients enables the models to be tested thoroughly by all the stakeholders. The requirements of the hospital and the forecast demand for the health services in terms of space, equipment, operational requirements, policies and staffing are developed in the planning phase; the architectural plan provides space requirements and design that reflect intra and inter-departmental relationships. Also budgeting and contract requirements can be inferred from the schematic design.

The activities that occur in the healthcare process are to be explained and charted for modeling. For example, a step-by-step process of a patient brought by

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[7] Pull production: System where parts, supplies, information, and services are pulled by internal and external customers exactly when they are needed. (Black et al., 2008)

paramedics into the ED may be considered, helping in problem formulation and process identification. Process stages, sequence, and times are extracted from the Value Stream Map current state. These data form the basis for the post-lean simulation model. Table 3 illustrates the current state data of both processes and resources. These data are inputted into an ED *AnyLogic* simulation model. The software, based on the Java platform, simulates both current state and future state processes.

Figure 30 shows the generic built model.

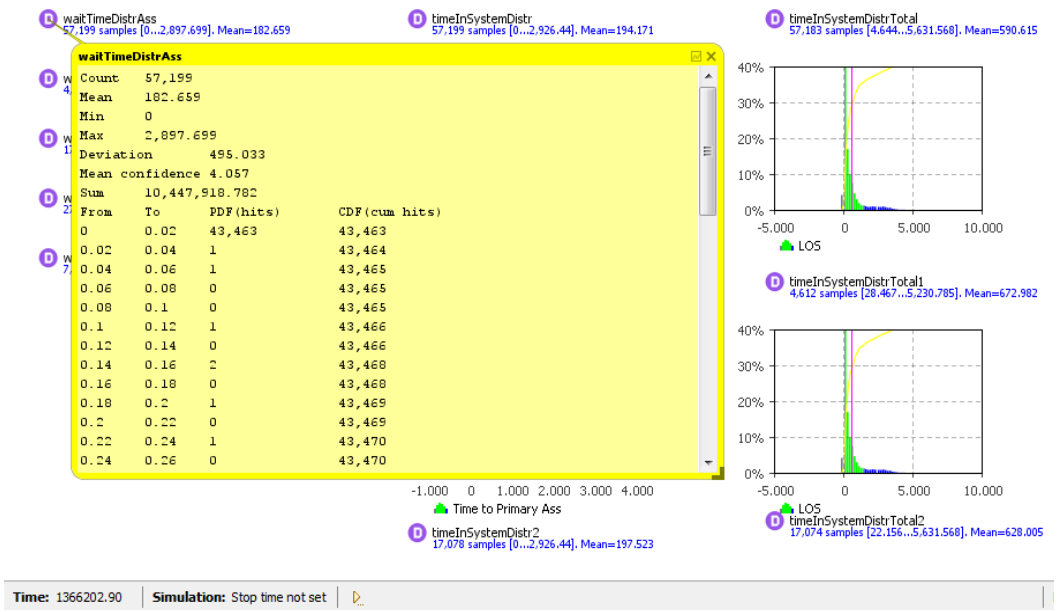

Figure 30 Wait Time in ED Future State Process

Modeling ED Process – Current State

Patients presented to the ED for examination and treatment go through multiple stages in the main ED or Ancillary Departments before being discharged home or admitted to the Inpatient Unit; Chapter II Section 2.2 illustrates the main processes.

Patient Arrivals and Data Distribution: The Canadian Triage and Acuity Scale (CTAS) assesses ED patients to ensure that they receive treatment according to clinical urgency rather than their order of arrival. In 2003-2004, only 0.5% of those arriving at EDs were triaged as most severe (CTAS I for example, major trauma, shock, severe respiratory distress). The majority of cases (57%) were assessed as either less-urgent (CTAS IV, for example, chronic back pain, not sudden headache, mild allergic reaction) or non-urgent (CTAS V, for example, sore throat, menses, isolated diarrhea). The average number of patients presented daily to the ED in our case study is 200, almost 70% of whom presented during the peak hours, which extend from 10 AM to 10 PM. Figure 31 shows the daily ED patients' arrival based on CTAS levels.

On entry into the model, the system generates patient entities with given sets of attributes, one of which is the arrival time, which is used to compute intermediate processing and waiting times, along with average LOS statistics. To imitate ED arrival distribution, arrivals are generated following a data table distribution, in which the likelihood of an arrival in a specified interval is independent of the arrival times of the previous patients.

ED Hourly Visits per Patients' Severity Levels

Hour	CTAS I & II	CTAS III	CTAS IV	CTAS V	All
1	0	1	2	1	5
2	0	1	2	1	4
3	0	1	1	0	3
4	0	1	1	0	3
5	0	1	1	0	2
6	0	1	1	0	2
7	0	1	1	0	3
8	0	2	3	1	5
9	1	3	4	1	9
10	1	4	6	2	12
11	1	4	6	2	13
12	1	4	6	2	13
13	1	4	6	2	12
14	1	4	6	2	12
15	1	4	6	2	12
16	1	3	5	2	11
17	1	3	5	2	11
18	1	3	5	1	10
19	1	3	5	2	11
20	1	4	6	2	12
21	1	3	5	2	11
22	1	3	5	1	10
23	1	2	4	1	8
24	1	2	3	1	6
Total Number of Visits (per day)	**16**	**60**	**96**	**28**	**200**

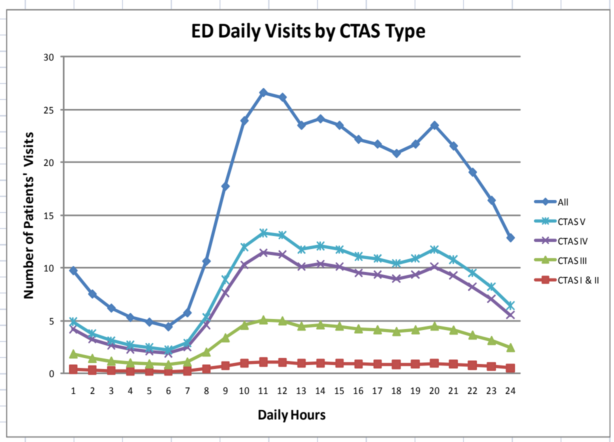

Figure 31 Daily ED patients' arrival based on CTAS levels.

Figure 32 shows the ED patients' distribution according to their CTAS levels; the statistics are of the catchment area of Erie-St. Clair Region, where Hôtel-Dieu Grace Hospital in Windsor - Ontario, is located.

Severity of ED Patients

CTAS I 0.5%

CTAS II 8%

CTAS III 30%

CTAS IV 48%

CTAS V 14%

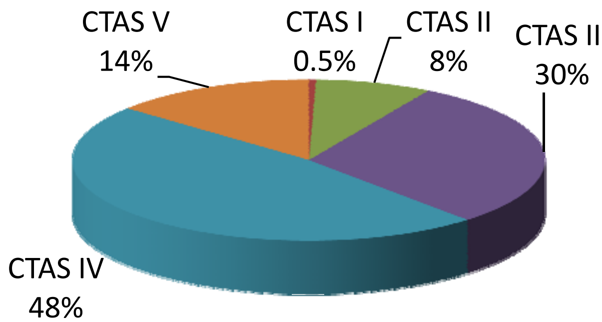

Figure 32 Distribution of ED patients' severity levels in Erie-St. Clair Region, ON (Canadian Institute for Health Information, 2005).

The statistical tables of patients' arrival distributed over the daily hours generate patients' arrival in the simulation model. The generated entities' distribution is nearly identical to the statistical table, as shown in Figure 33.

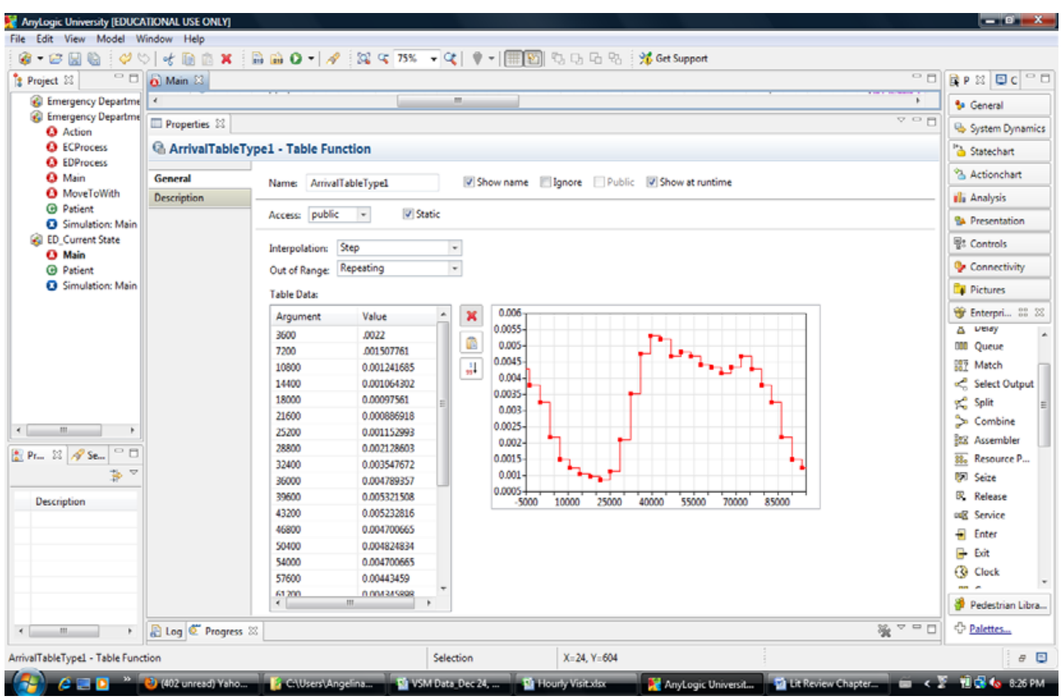

Figure 33 Patients' arrival data table in AnyLogic simulation software.

Triage: Following arrival, patients move to triage, where each modeled patient is triaged according to his CTAS level. Appendix A illustrates the statistical distribution in the catchment area of Erie-St. Clair Region, ON. In the simulation, patients are seen in the order defined by their CTAS level first (with lowest CTAS level being given highest priority) and in their order of arrival within each category second. Patients assigned a CTAS I level proceed directly to a main ED bed, whereas CTAS II and III patients proceed to the waiting area. If one of the 20 beds is available, the next patient in the waiting area proceeds to it. When all beds are occupied, CTAS II and III patients remain in the waiting area until one of the beds becomes available. In the same fashion, CTAS IV and V patients remain in the waiting area until one bed becomes available. In the following process steps in ED, patients will be prioritized or routed to care according to their CTAS level.

Waiting Area: There is one waiting area in the simulation with no limit on the number of patients it can accommodate.

Main ED: In the simulation, the main ED consists of 20 exam beds, 4 attending physicians, 7 nurses (Triage and RN are included), and 12 observation rooms. Once a patient occupies a main ED bed, the simulated process is broken down into three steps. First, the patient spends time with a physician for an initial assessment, and may have to wait if all physicians are busy with other patients. Then the patient spends time without the physician, during which treatment and diagnostic tests are conducted. Note that nursing, ancillary staff, consultant time, laboratory, and radiology resources are not specifically modeled but are given dedicated steps in the process and time. Finally, the patient spends 10 more minutes with the physician before being admitted or discharged. Table 2 lists the times patients spend receiving care or waiting during their visit to ED.

Admission and Boarding: The proportion of patients who were routed to admission in the simulation was based on statistics presented in Chapter 2. The distribution of patients admitted to Inpatient Unit or routed to exit ED as per their CTAS levels was not modeled. If an inpatient bed is not available, patients will occupy an observation bed until a bed becomes available in the appropriate inpatient unit. Patients with CTAS I proceed to exit the ED into an inpatient bed and bypass other patients with less severe acuity levels who are waiting for admission to Inpatient Unit. The remainder also exit the ED, either by being discharged or dying.

Exit ED: All admitted or discharged simulated patients leave the system through the two locations where statistical data is collected.

Figure 34 shows the Current State model in *AnyLogic* simulation software. Figure 35 to 39 are snap shots of the simulation model and its corresponding statistical data such as wait times and LOS.

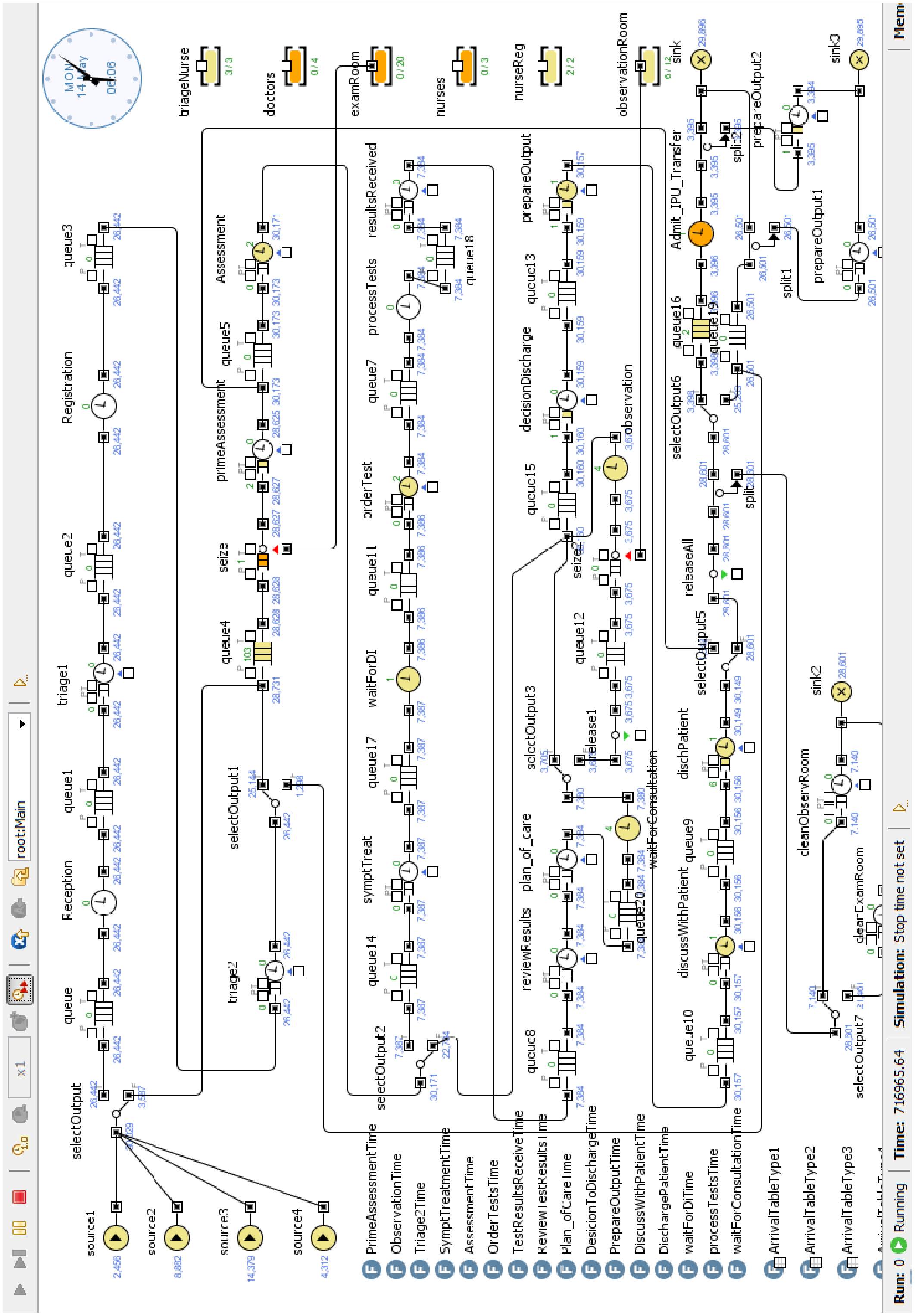

Figure 34 *AnyLogic* DES model of ED current state process.

timeInSystemDistr

Count	230,690
Mean	2,206.315
Min	0
Max	10,402.807
Deviation	1,856.194
Mean confidence	7.575
Sum	508,974,708.447

From	To	PDF(hits)	CDF(cum hits)
-0.35	306.85	39,661	39,661
306.85	614.05	9,891	49,552
614.05	921.25	10,815	60,367
921.25	1,228.45	11,413	71,780
1,228.45	1,535.65	16,263	88,043
1,535.65	1,842.85	21,179	109,222
1,842.85	2,150.05	20,071	129,293
2,150.05	2,457.25	19,085	148,378
2,457.25	2,764.45	17,034	165,412
2,764.45	3,071.65	13,145	178,557
3,071.65	3,378.85	8,694	187,251

Figure 35 Snap shot of wait for initial assessment.

timeInSystemDistr

Count	9,268
Mean	18,371.507
Min	6.729
Max	78,298.741
Deviation	24,825.639
Mean confidence	505.433
Sum	170,267,130.637

From	To	PDF(hits)	CDF(cum hits)
-6.85	1,652.03	5,007	5,007
1,652.03	3,310.91	96	5,103
3,310.91	4,969.79	103	5,206
4,969.79	6,628.67	84	5,290
6,628.67	8,287.55	97	5,387
8,287.55	9,946.43	101	5,488
9,946.43	11,605.31	93	5,581

Figure 36 LOS of ED current state process.

timeInSystemDistrTotal

Count	56,265
Mean	777.332
Min	12.807
Max	7,312.535
Deviation	860.703
Mean confidence	7.112
Sum	43,736,603.711

From	To	PDF(hits)	CDF(cum hits)
-32.64	186.24	14,816	14,816
186.24	405.12	12,336	27,152
405.12	624	6,713	33,865
624	842.88	4,629	38,494
842.88	1,061.76	3,564	42,058
1,061.76	1,280.64	2,730	44,788
1,280.64	1,499.52	2,304	47,092

Figure 37 Snap shot of total wait in the system.

waitTimeDistr

Count	3,644
Mean	0.192
Min	0
Max	8.286
Deviation	0.685
Mean confidence	0.022
Sum	701.201

From	To	PDF(hits)	CDF(cum hits)
0	0.32	3,262	3,262
0.32	0.64	70	3,332
0.64	0.96	45	3,377
0.96	1.28	32	3,409

Figure 38 Wait time of ED current state process.

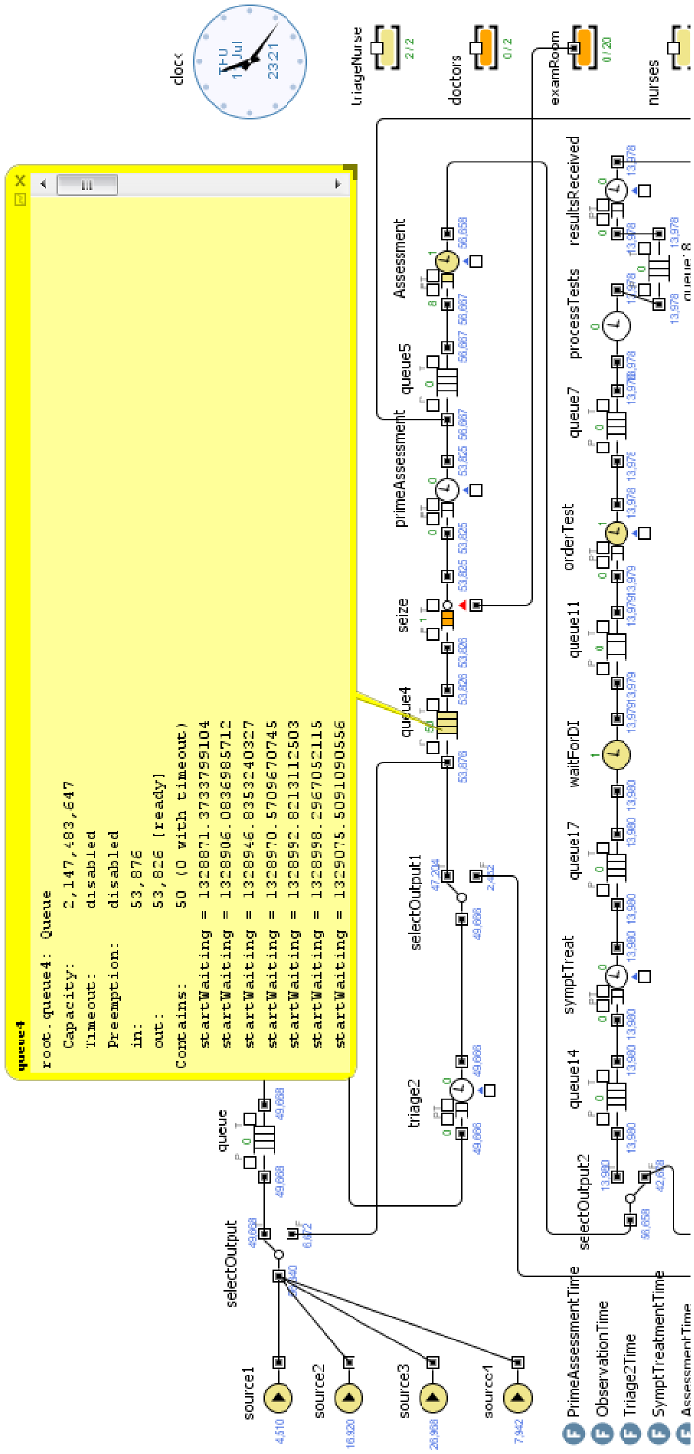

Figure 39 LOS of ED current state process.

After multiple tests and model runs, which generated over 50000 entities, the collected LOS statistical data and wait time, and physical and human resource utilization were organized in

Table **4**, respectively.

Table 3 Statistical results of ED current state process resources

The Current State Model Output										
	Count	Mean		Min		Max		Deviation	
		Mins.	Hrs.	Mins.	Hrs.	Mins.	Hrs.	Mins.	Hrs.
LOS (from Admit to Discharge)	56265	777	12.95	12.00	0.20	7312	121.87	860.00	14.33
CTAS I & II	4504	1008	16.80	15.00	0.25	7312	121.87	1040.00	17.33
CTAS III	16906	862	14.37	15.00	0.25	7185	119.75	903.00	15.05
CTAS IV	26923	727	12.12	12.00	0.20	5485	91.42	812.00	13.53
CTASV	7932	633	10.55	13.00	0.22	5047	84.12	763.00	12.72
LOS (from Admit to Prime Assess)	53822	403	6.72	0.00	0.00	3790	63.17	660.00	11.00
CTAS I & II	4305	413	6.88	0.00	0.00	3719	61.98	666.00	11.10
CTAS III	16158	397	6.62	0.00	0.00	3771	62.85	651.00	10.85
CTAS IV	25747	408	6.80	0.00	0.00	3790	63.17	667.00	11.12
CTASV	7615	393	6.55	0.00	0.00	3781	63.02	651.00	10.85
Wait time (before Prime Assess)	53822	360	6.00	0.00	0.00	3762	62.70	651.00	10.85
CTAS I & II	4305	402	6.70	0.00	0.00	3696	61.60	657.00	10.95
CTAS III	16158	386	6.43	0.00	0.00	3747	62.45	643.00	10.72
CTAS IV	25747	396	6.60	0.00	0.00	3755	62.58	659.00	10.98
CTASV	7615	382	6.37	0.00	0.00	3752	62.53	643.00	10.72

Table 4 Physical and human resource utilization in current state model

Resource Type	**Utilization**
Observation Room (12 rooms)	24.70%
Nurse (min 2 - max 4 nurses)	83.30%
Doctor(min 2 - max 4 doctors)	81.10%
Exam Room (20 rooms)	83.80%
Triage Nurse (min 2 - max 3 nurses)	33.90%

Ancillary Departments

While the aforementioned results concern the main ED processes and models, ancillary departments play an essential role in reducing LOS and waiting time. Surgical Departments, Diagnostic Imaging, and the Laboratory are major ancillary departments on which the ED depends to diagnose and treat patients. These departments affect the process flow, as it may take between 30 to 180 minutes to receive results (sometimes more with complicated cases). Currently, these departments are not prepared to provide services in a timely manner.

ED process is also inefficient at discharging patients to free ED beds and stretchers. Patients who are ready to be discharged from ED either go home, or are admitted to the Inpatient Unit in the hospital. Although discharging patients to their home is usually a smooth process, discharging them to Inpatient Unit is a far more difficult process, as statistical data indicates that the average waiting time for an empty bed is 45 minutes. To ease the operation of discharging ED patients, hospital beds should be freed more frequently, or more beds should be provided for admitted patients.

3.2.1. The Future State Process Enhancement

In applying the above discussed concepts and principles from Chapter II, Section 2.2, a series of enhancements to the current state process and funnel shape design concept are proposed in Table 5. Table 6 shows the current process stages of the ED listed alongside the proposed changes.

Table 5 ED Functional Current Practice vs. the Proposed Changes

Design Change Table

#	Stage	Current	Cause for change	Proposed Change
1	Patient Arrival Stage	Big waiting room	Smaller waiting room allows for more examination / observation rooms	Assign more spaces for functions that need them more
2		ED receives more patients than anticipated, short of staff and spaces	Overcrowding and capacity issues	Plan for more capacity than anticipated
3		Walk-in patients are admitted depending on triage priority	75% of ED patients are a non-urgent that burden the system and require attention while waiting for hours	Admitting walk-in patients is on the basis of first in
4	Triage & Registration Stage	Specialized modules/cluster	Exhausted staff of working on same patient care level	Distribute patient care level spaces across modules
5		Modules rooms for care types	Eliminate flexibility	Universal spaces that allow flexible use
6		Different room size and design	Increase error and consume more time to operate	Identical space design
7		Triage stage is not a decision making one, computer software is used to assess the acuity level of patients	Delay process	Rapid triage concept with multiple triage stations
			Long non-urgent patients wait times	Provide treatment and discharge non-urgent patients to reduce patients load by combining triage and fast track
			Medical records is not assigned to patients that allows performing further tests	Implement rapid registration /issue patient identification number while patients in triage
			Help in making more informed decision about patients' conditions	Advanced triage functions that allow triage personnel to collect specimens and send patient directly to imaging
			75% of ED patients are a non-urgent that burden the system and require attention while waiting for hours	Eliminate triage and fast forward patients to examination rooms
8		Paper based registration	it slows down the process and delay performing some needed tests for patients	Implement bed side registration. It is a Lean concept when registration can be performed while patients waiting for another stage
9	Assess Patient Stage	Linear process approach of first nurse assessing patient condition, then the physician	patients have to tell their stories many times in ED	Patients can tell their stories once, assessment and treatment can start with no delay
			Process takes longer and involves more wait	
10	Additional Examination Stage	Diagnostic Imaging Department service is slow	Longer waiting for patients being serviced specially with high volume, and wait for communication and receiving results	Having imaging facility and/or CT scanner * in ED enhances patient flow**
				Block imaging rooms within DI as needed for ED patients
11		Laboratory service is slow	slow turnaround and delivery of hospital lab results that delays ED flow	Streamline lab system and/or give ED test a priority
			Ordering tests is delayed in the process due to communication issue and protocols	Make arrangement in communicating and in process protocols to give priority to ED test ordering
				A pneumatic tube system between ED and lab to cut down turnaround time and save travelling distances
12		Pharmacy service is slow	Slow turnaround and delivery of hospital pharmacy	Streamline lab system and/or give ED orders a priority
				A pneumatic tube system between ED and pharmacy to cut down turnaround time and save travelling distances
				Include a satellite clinical pharmacy in ED

13	Treatment Stage	Designated observation space	Can be underutilized and turn into a storage area It takes valuable spaces of ED rooms and delay process	Integrating it in the department and using it as an examination room
14	Discharge Stage	Delay in discharging patients	Process flow is slow	Block beds for ED patients in IPU, and give ED patient admission a priority to IPU beds
15	General Process Improvements	Designated resources for each specialized room (equipments, etc)	Larger number of identical equipments needed, redundancy	Shared resources
16		Design first	Resource requirements are not being met/don't fit	Figure out operational needs first, design second
17		Centralized nurses' station and utilities rooms	staff have to return to centralized areas to perform work/ be away from patients	Decentralized workstations to allow staff access to computers without the need to return to central control area/ be close to patients/ utilities rooms are closer to distribute locations
18		Centralized supplies and materials	A lot of movement in the department and cause congestions corridors	Decentralized supplies and materials to patient zones with minimal movement- Lean concept, waste of transportation
19		Physicians and nurse rooms are at the other corner of ED	Waste of travel and time as medical personnel have to walk longer distances to get to examination rooms	Position related medical personnel rooms closer to where the action is, (perform spaghetti diagram/optimization model to determine optimal location)
20		Specialized staff	More staff needed, redundancy	Sharing staff
21		Treatment room spaces are taken up by other services	Less designated areas for treatment affect the number of patients an ED can take	Make the ED both patient and staff friendly by balancing treatment and support spaces. Support spaces might include: - Trauma services administrative and support suites - Flight services command centre, administrative spaces - Police substations, including holding cells - Other speciality suites and administrative spaces
22		Entering patients data in the tracking system	Not knowing where patients are located	Wireless tracking devices to be attached to patients at all time
23		ED design is still done in static state	Poor understanding of the effect of adjacencies and distances, workflow patterns, staffing.	Use of modeling tools that allows design to be based on time/motion parameters
24		Rooms are left empty for longer than expected	Examination/treatment rooms are not known if empty or occupied	Propose either sophisticated computerized tracking systems that shows the ED resources Propose Hijunka Box, where cards can be placed at nurse desk to indicated available rooms/resources
25		Care is not delivered in the right time	Delay in treatment/ longer waiting time/ less satisfied patients	Right care to right people in the right time
26		Process flow is congested and going backwards in the movement	waste of transportation and time	Process flow: no going backwards in the movement. Always moving forwards

*Access to CT scanners should be from trauma rooms, while access to radiology services is for both ambulatory and non-ambulatory patients, it recommended to locate imaging services area off the triage area

*it is recommended to include imaging and CT scan services in ED when having more than 20,000 annual visits (Huddy, 2006, page 163), it also recommended to have one radiology room for every 20,000 to 25,000 annual patients visits.

Table 6 Physical and Human Resource Utilization in Current State Model

Current State Processes

Activity #	Perfromed By	Activity	a	c (mode)* Low	c (mode)* High	b
1	Clerk	**Reception**	0.1	2.6		5
		Queue	0.1	5.05		10
2	N	**Triage 1**	0.3	0.7		1
		Queue	0.1	15.1		30
3	Clerk	**Registration**	0.5	5.3		10
		Wait	0.5	30.3		60
		Queue	0.5	120.3		240
4	RN	**Triage 2**	5	8.8	16.3	20
		Wait	0.5	15.4	45.1	60
		Queue	0.5	150.4	450.1	600
5	RN	**Primary Assessment**	10	11.3	13.8	15
		Queue	0.5	75.4	225.1	300
6	MD	**Assessment**	0	22.5	67.5	90
		Wait	0.5	12.8		25
7	N	**Symptomatic Treatment**	0.5	7.9	22.6	30
		Wait	1	60.5		120
8	D/N	**Order Lab / DI Test(s)**	5	33.8	91.3	120
		Wait	0.5	60.3		120
		Queue	0.5	22.9		90
9	N	**Test Results Received**	1	2.5	5.5	7
		Queue	0.5	60.3		120
10	D	**Review Results**	0.2	1.4	3.8	5
		Wait	1	90.5		180
11	D	**Plan of Care**	0.2	1.4	3.8	5
		Wait	15	727.5		1440
12	N	**Observation**	0.5	180.4	540.1	720
13	D	**Decision to Discharge**	0.2	0.4	0.8	1
14	D	**Prepare Output**	0.5	1.6	3.9	5
15	D	**Discussion with Patient**	0.5	7.9	22.6	30
		Wait	5	33.8	91.3	120
16	N	**Discharge Patient**	0.5	7.9	22.6	30
		Wait	2	31.0		60
17	HK	**Prepare Room and Bed**	2	4.0	8.0	10
18	N	**Prepare Output**	0.5	1.6	3.9	5
19	N	**Follow-up Call Backs**				

Future State Processes

Perfromed By	Activity	Stations	a	c (mode) * Low	c (mode) * High	b
Clerk	Reception	Pod 1 - Reception	0.1	2.6		5
N	Nurse Assessment		0.3	0.7		1
	TOTAL		**0.4**	**3.2**		**6**
MD/RN	Assessment	Pod 2 - Assessment and Treatment	10	**30.0**	70.0	90
N	Apply Treatment		0.5	7.9	22.6	30
N/D	Observation		0.5	180.4	540.1	720
Clerk	Bedside Registration		0.5	5.3		10
	TOTAL		**11.5**	**221.1**	**640.4**	**850**
D/N	Order Tests (educed by 50%)	Pod 3 - Tests	5	18.8	46.3	60
N	Receive Results		1	2.5	5.5	7
D	Review Results		0.2	1.4	3.8	5
D	Plan of Care		0.2	1.4	3.8	5
	TOTAL		**6.4**	**24.1**	**59.4**	**77**
D	Decision to Discharge	Pod 4 - Discharge	0.2	0.4	0.8	1
D	Prepare Output		0.5	1.6	3.9	5
D	Discussion with Patient		0.5	7.9	22.6	30
N	Discharge Patient		0.5	7.9	22.6	30
	TOTAL		**1.7**	**17.8**	**49.9**	**66**
HK	**Prepare Room and Bed**	Pod 5- Housekeepi	2	4.0	8.0	10
N	**Prepare Output**		0.5	1.6	3.9	5
N	**Follow-up Call Backs**					
	TOTAL		**2.5**	**5.6**	**11.9**	**15**

Abreviations

N	Nurse
RN	Registered Nurse
MD	Medical Director
HK	House Keeping
D	Doctor
*	Mode presented for Low/High when Severity of illness level has an effect

Modeling the ED Process – Future State

In modeling the future state simulation, the current state model was embellished to reflect changes proposed in Table 5. Figure 40 shows *AnyLogic* Discrete Event Simulation Model of ED Future State Process. Figure 41 and Figure 42 show snapshots of the *AnyLogic* post-lean simulation of the future state model .

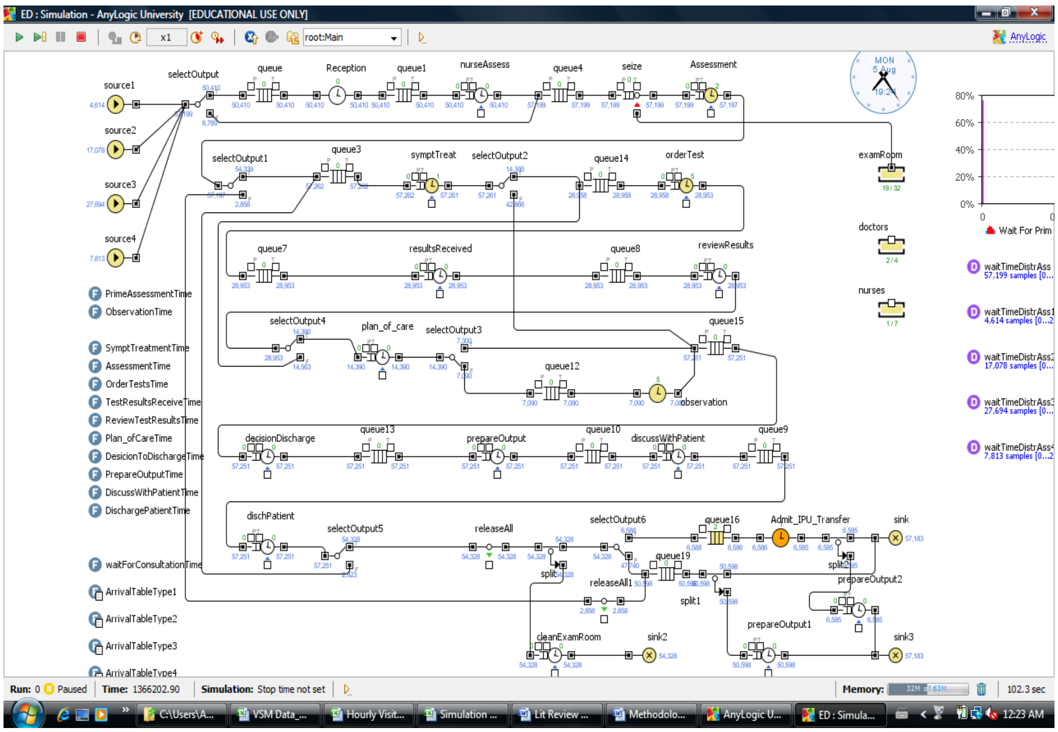

Figure 40 *AnyLogic* Discrete Event Simulation Model of ED Future State Process

timeInSystemDistr

Count	57,199		
Mean	194.171		
Min	0		
Max	2,926.44		
Deviation		503.805	
Mean confidence		4.129	
Sum	11,106,407.795		
From	To	PDF (hits)	CDF (cum hits)
-0.01	61.43	44,172	44,172
61.43	122.87	1,528	45,700
122.87	184.31	1,204	46,904
184.31	245.75	1,281	48,185

Figure 41 Snapshot LOS of ED Future State Process

timeInSystemDistrTotal

Count	57,183		
Mean	590.615		
Min	4.644		
Max	5,631.568		
Deviation		759.436	
Mean confidence		6.225	
Sum	33,773,156.628		
From	To	PDF (hits)	CDF (cum hits)
-106.47	66.33	2,381	2,381
66.33	239.13	22,860	25,241
239.13	411.93	9,696	34,937
411.93	584.73	5,642	40,579
584.73	757.53	4,253	44,832
757.53	930.33	2,633	47,465
930.33	1,103.13	1,687	49,152
1,103.13	1,275.93	1,061	50,213
1,275.93	1,448.73	751	50,964

Figure 42 Snapshot LOS of ED Future State Process

The statistical results of ED Future State are illustrated in Table 7; the data collected are of three main indicators of time spent in ED; LOS from Admitting to Discharge, LOS from Admitting to Primarily Physician Assessment, and Waiting Time before Primarily Physician Assessment.

Table 7 Statistical Results of ED Future State Process Resources

The Future State Model Output										
	Count	Mean		Min		Max		Deviation	
		Mins.	Hrs.	Mins.	Hrs.	Mins.	Hrs.	Mins.	Hrs.
LOS (from Admit to Discharge)	54014	558	9.30	8.00	0.13	5371	89.52	768.00	12.80
CTAS I & II	4253	640	10.67	31.00	0.52	5371	89.52	772.00	12.87
CTAS III	16242	584	9.73	19.00	0.32	5021	83.68	766.00	12.77
CTAS IV	25849	549	9.15	11.00	0.18	5190	86.50	773.00	12.88
CTASV	7670	490	8.17	8.00	0.13	4893	81.55	749.00	12.48
LOS (from Admit to Prime Assess)	54025	186	3.10	0.00	0.00	3636	60.60	519.00	8.65
CTAS I & II	4253	182	3.03	0.00	0.00	3593	59.88	510.00	8.50
CTAS III	16245	182	3.03	0.00	0.00	3661	61.02	514.00	8.57
CTAS IV	25857	190	3.17	0.00	0.00	3651	60.85	527.00	8.78
CTASV	7670	181	3.02	0.00	0.00	3663	61.05	511.00	8.52
Wait time (before Prime Assess)	54020	176	2.93	0.00	0.00	3635	60.58	511.00	8.52
CTAS I & II	4253	177	2.95	0.00	0.00	3566	59.43	502.00	8.37
CTAS III	16245	177	2.95	0.00	0.00	3615	60.25	505.00	8.42
CTAS IV	25857	185	3.08	0.00	0.00	3641	60.68	518.00	8.63
CTASV	7670	176	2.93	0.00	0.00	3630	60.50	502.00	8.37

The statistical analysis of physical and human resources Utilizations are presented in Table 8

Table 8 Physical and Human Resource Utilization in Future State Model

Resource Type	Utilization
Nurses (min 4 - max 7 nurses) *	37.60%
Doctors (min 2- max 4 doctors)	79.80%
Exam Room (32 rooms) **	47.70%

* Includes triage nurses.

** Exam rooms and observation rooms were clustered together in this model.

3.4 Achievement

The application of Value Stream Mapping for both current and future states indicates that ED processes can be categorized by two types of lean pull systems that affect patient flow, and consequently waiting time:

Type 1: Consists of CTAS IV & V patient types when volumes are high and lead times are short and stable. This type requires queues between processes. The challenge here is to enhance the capability of moving patients from one stage to another to minimize queues[8].

Type 2: Consists of CTAS I, II & III patient types, as frequency is lower and patient lead time is longer. Unlike the Type 1 process, and due to a low number of patients, lengthy queues are not examined. It is important to establish a system that can accommodate both types of processes.

The Post-Lean Simulation model was applied and incorporated the above-examined process characteristics such as process stages, sequence, and times. After running the model and generating over 50,000 entities in the current state model, statistics and resource utilization data were collected and summarized. The model was then embellished and future state changes were applied. In this model, the overall waiting time for a doctor's examination improved between the current and future state. Future state process improvement showed a decrease in LOS by almost 30%. The overall waiting time for a doctor's examination[9] has also improved between current and future states by 48%. Table 9 summarizes these findings.

Table 9 Simulation Model Outcomes and Recorded Improvements

	Current State (minutes)	**Future State** (minutes)	**Improvement**
Average LOS	777	558	33%
Average Wait Time	360	176	48%

[8] Other initiatives aimed at reducing the load of CTAS IV & V patients from seeking treatment at EDs have established primary care and urgent care centres that provide access to treatment for those types of patients.

[9] Healthcare providers mandate that all patients-no exception- must be examined by an ED physician for treatment, observation and discharged.

Resource utilizations have also decreased for doctors by 2%. Nurse utilization in the current state is at 83.3% and 37.9% for nurses and triage nurses, respectively. In the future state, usage is 37% for both types of nurses (as they were combined together as no triage stage exists in this model). Exam rooms' utilization is 83.8% and that of observation rooms is 24.7% (under-utilized) in the current state. In the future state, observation and exam rooms are combined for flexible use by all patient types; in this case, the utilization is 47.7%. The future state model has shown a decrease in waiting time and LOS, in turn, enhancing the patient's experience while visiting the ED. There is a correlation observed between the time a patient waits to see a physician and his severity level. The most severe level patients had the shortest waits, with a median of approximately five minutes. However, 10% of these patients were seen immediately (10th percentile = 0 minutes) whereas another 10% waited 45 minutes or more (90th percentile).

Waiting and LOS are two important factors affecting patient satisfaction when visiting the ED. At more severe levels, patient conditions deteriorate by waiting and not having access to timely care. This situation places more pressure on ED professionals as some patients require monitoring and immediate treatment. Future state process improvement showed a decrease in LOS by almost 30% from a mean of 777 minutes to 558 minutes. Lengthy queues have two major negative impacts on ED, as they increase work load for professionals and decrease the capability of serving other patients. The overall waiting time for a doctor's examination has dropped by 48% between the current and future state models, with a mean of 360 minutes and 176 minutes, respectively. Also, resource utilizations have decreased for doctors by 2%. The improvements result from the implementation of Lean Healthcare principles that preserve process stages that add value to patient treatment, eliminate various waste aspects, and recommend ED architectural design principles and standards that impact functional processes. Several, either base or embellished, post-lean simulation models were tested to measure the significance of suggested changes. This research confirms the correlation between the time patients wait to see a physician and their severity levels as expected. Another correlation exists between the time a patient waits to see a physician and the time of the day that patient arrives at the ED that has an effect on waiting time and LOS, and requires staff scheduling adjustment.

3.5 Limitations

Modeling ED processes in Post-simulation stage has the following limitations:

- Death is not modeled as the effect on the outcome is negligible.
- Left Without Being Seen is not modeled as patients may choose to leave - at any given moment in the process – without being seen by a physician[10].

[10] As explained in Chapter II, Section 2.3, patients may choose to leave without being seen by a physician. Patients with CTAS I and II are unlikely to leave without being seen; however, percentages CTAS III, IV and V patients leave without being seen if not placed into a bed within random periods time of presenting to the ED. As EDs' capacity to serve patients is less than the demand, patients left without being seen brings the system to equilibrium.

Chapter IV Conclusion

5.1 Conclusion

Researchers have proposed methods to manage hospital congestion, and in particular, ED patient flow. The architectural design, process design, and the already established ED standards affect the artificial variability of waiting time and LOS. A decrease in this variability would improve ED output, and subsequently, ED congestion and patient experience. Other researchers have shown a correlation between hospital occupancy and ED length of stay. An improved patient admission rate to inpatient units provides a solution to long waiting times for ED patients. The aforementioned strategies decrease the time patients wait in the ED for hospital admission, decrease the ED length of stay, and free ED bed space to treat new patients in need of care. The ED simulation model suggests that adopting an improved design scheme and applying Lean Healthcare concepts would improve the rate at which admitted patients depart the ED, and decrease the ED length of stay, therefore reducing congestion.

Historically, patient treatment spaces have been designed based on patient satisfaction principles that may influence the healing process. In the last few decades, medical professionals or users are usually involved in designing EDs, determining process requirements, and selecting equipment. However, it is crucial to add patients to a user-friendly concept; they are considered the process owners, and the end product (design) is required to be not only professional-focused but patient-focused as well.

Waiting times and LOS are two important factors affecting patient satisfaction when visiting EDs. Patients' conditions, especially at the Low Severe acuity level, deteriorate without access to timely care. This situation places more pressure on ED professionals, as some patients require monitoring and immediate treatment. Lengthy queues have negative impacts on the ED as they increase professionals' work load, and decrease their ability to serve other patients. Different strategies are applied to reduce waiting time. Fast-tracking separates non-severely ill from severely ill patients; however, this approach is not widely implemented. Furthermore, the analysis shows that the current ED design practice ignores the effect of ancillary departments on ED waiting time. To reduce their effect, and eliminate competition with the hospital for their services, strategies such as establishing X-Ray and CT-scan services, Laboratory, and Pharmacy services within the ED are applied. Another mitigating method is to create a schedule that blocks both physical and human resources within the DI, Laboratory, Pharmacy, and ORs to service ED patients. Another element that affects waiting time is recognizing and dealing with psychiatric or mentally ill patients and providing appropriate ways of intervention; however, this practice is applied at a very limited scale.

Improvements are made possible by implementing Lean Healthcare Principles. These principles focus on preserving process stages that add value to patient treatment and eliminating all aspects of waste. Improvements have also resulted from applying ED architectural design principles and standards, which impact functional processes, testing and examining the correlated LOS and waiting time, and studying the LOS and architectural design standards in the simulation model. Several, either base or embellished, post-lean simulation models were tested to measure the significance of suggested changes.

5.2 Research Contribution

The implementation of the above-described methodology allowed for further understanding of the functional process and identification of the inefficiencies and bottlenecks that resulted in excessive ED waiting, and the effect of ED ancillary departments on waiting times. the methodology also incorporated new design principles that are not specific to the healthcare field; but rather, applicable to making functional processes more efficient and the physical environment more user friendly. The research contributions can be summarized in the following:

- A Streamlined Design Scheme has been proposed to replace the existing Funnel Design Scheme
- A reduction in average LOS has been achieved, which adds a positive value to patient experience while in the ED.
- Process steps that are necessary and valuable to the patient's experience have been identified,
- The effect of the co-relationship and inter- departmental process flow that is ignored in current architectural design standards has been identified.
- Waste has been reduced in the future state VSM.
- The architectural and engineering standards of ED have been assessed based on the principles of a patient-focused environment design approach.
- Utilizations, of both physical and human resources have been identified and optimized in seeking reduced waiting time to arrive at "universal zero delay treatment." However, waiting time would not reach "zero" value.

5.3 Areas for future research

Every ED design has the potential to either increase or decrease throughput time. Inter-departmental relationships are key factors in developing a system that operates in harmony and supports wait reductions instead of creating longer queues. The investigation of the impact of these departments on waiting time and LOS needs to be examined to arrive at measurable standards. Testing different approaches will eliminate the negative impact on both ED LOS and waiting times while maintaining effective inter-departmental service processes.

It was expected that the best practices implementation, obtained through the simulation/modeling tool that identified the value proposition of ED operating scenarios, would face the challenge attaining continuous improvement for operational metrics that lead to achieve the concept of "Zero Delay Treatment". More investigation and research are required, more specifically in the clinical field, to achieve a break-through in ED process design and arrive at "Zero Delay Treatment."

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Appendices

Appendix A: History of ED Practice

Appendix B: Variable Calculations and/or Definitions

Appendix C: Bimaristan Al-Nouri Overview

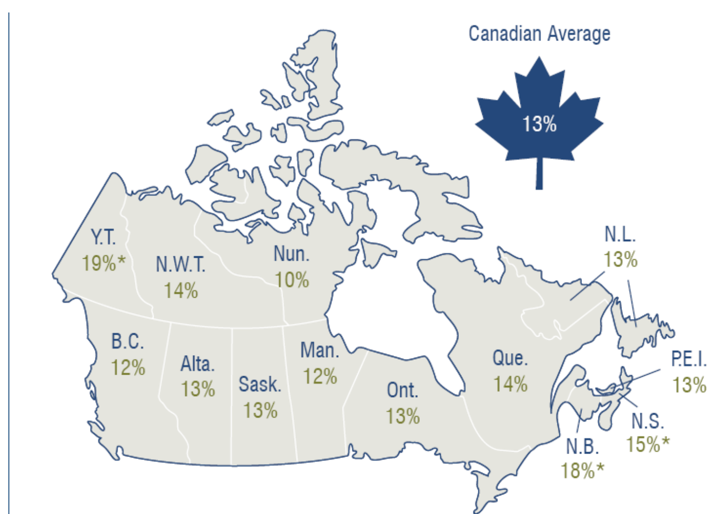
Appendix D: Variable Calculations and/or Definitions

Appendix E: Bimaristan Al-Nouri Overview

2.4.4 Use of EDs in Canada

Each year, millions of Canadians visit EDs for treatment of various health conditions, life-threatening or trauma-related, or most commonly, non-urgent health conditions. In 2001, Statistics Canada reported that more than 23 million Canadians 15 years and older (94% of Canadians) accessed at least some type of "first contact" health service. For some, that entailed visiting their family doctor or a walk-in clinic; while for others, the first contact service was a hospital's emergency department. In 2003, Statistics Canada reported that 3.3 million Canadians aged 15 or older were most recently treated by, or had their most recent contact with, a health professional in an emergency department. (Canadian Institute for Health Information, 2005)

Statistics Canada asked Canadians where they received care for their most recent injury that required medical attention:1.2 million, or just over half (55%), said they went to an ED. The next most common places were doctors' offices (21%) and walk-in clinics (12%). Even among ED patients, however, there is a large variation in the severity of illnesses and injuries. Figure 43 illustrates percentages of patients treated in EDs across Canada (Canadian Institute for Health Information, 2005).



* Significantly different from estimate for Canada ($p < 0.05$).
Source: Carriere, G. "Use of Hospital Emergency Rooms." *Health Reports* 16, 1 (2004): pp. 35–39.

Figure 43 The use of EDs across Canada by provinces and territories (Canadian Institute for Health Information, 2005).

2.4.5 Patients' Arrival

Overall, 12% of those visiting EDs in 2003 - 2004 arrived by ambulance. The proportion of ED users who arrived by ambulance increased with age. Although the number of visits for those over 85 years old accounted for less than 3% of all

ED visits in that year, just over 52% of those in this age group arrived by ambulance. In contrast, those under age 5 represented almost 10% of all ED visits, but less than 5% of those in this age group arrived by ambulance. Figure 44 presents the distribution of patients arriving by ambulance by age group (Canadian Institute for Health Information, 2005).

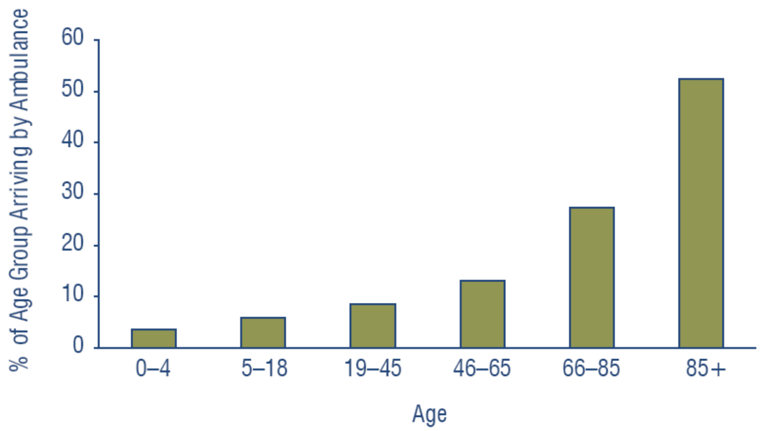


Figure 44 Percentages of patients arriving in EDs by ambulance, by age group (Canadian Institute for Health Information, 2005).

2.2.1 Severity of ED Patients

Assessed patients visiting EDs in Canada in 2003- 2004 revealed the following numbers: only 0.5% of those arriving at EDs were triaged as the most severe level of CTAS I (e.g., major trauma, shock, severe respiratory distress). The majority of cases (57%) were assessed as either less-urgent with CTAS IV (e.g. chronic back pain, not sudden headache, mild allergic reaction) or non-urgent with CTAS V (e.g. sore throat, menses, isolated diarrhea). Figure 45 shows the distribution of the patients visiting EDs according to their CTAS triage levels (Canadian Institute for Health Information, 2005).

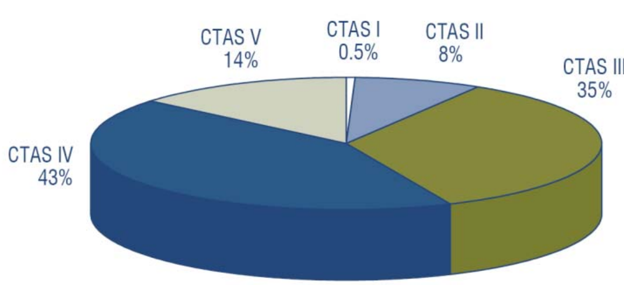


Figure 45 Distribution of ED patients' severity levels (Canadian Institute for Health Information, 2005).

"Overall, the distribution of ED patients by severity visiting selected Canadian EDs is similar to that observed in Australia. The U.S. uses a different four-point scale for assessing patients arriving at EDs, but still reflects relatively similar severity proportions for less than the most urgent visits. Urban-only EDs (Toronto-GTA and Calgary Health Region) tended to see a much lower proportion of non-urgent patients than the overall average" (Canadian Institute for Health Information, 2005). Table 10 illustrates the percentage of each CTAS level of ED patients' visits.

Table 10 Percentage of CTAS levels of EDs patients in Canada, US and Australia.

Triage Level	NACRS† (2003–2004) %	Toronto-GTA§ (2003–2004) %	Calgary Health Region^ (2004–2005) %	U.S.‡ (2002) %	Australia* (2003–2004) %
Classification Tool	CTAS	CTAS	CTAS	NHAMCS	National Triage Scale
Resuscitation	1	1	1	26	1
Emergency	8	14	18		8
Urgent	35	48	52	40	30
Less-Urgent	43	32	26	22	46
Non-Urgent	14	6	3	12	15
Millions of Visits	4.47	0.94	0.25	110.15	5.86

2.2.2 Patient Severity Differs Across Ontario

The distribution of Ontario's ED patients by severity level in 2003-2004 varied according to Local Health Integration Networks' regions. Local Health Integration Networks serving primarily urban populations witnessed a higher proportion of more severely ill patients than Local Health Integration Networks serving a more rural population (Canadian Institute for Health Information, 2005). Figure 46 shows the proportional distribution of ED visits on the CTAS scale.

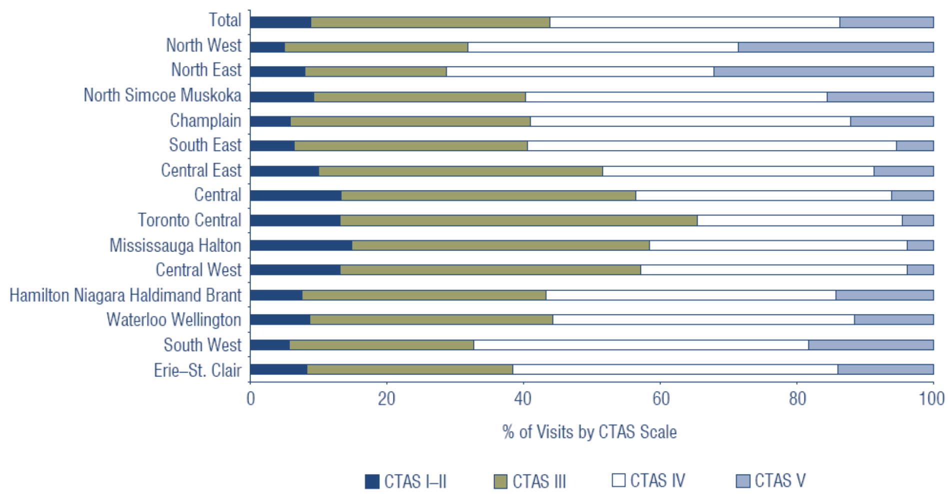


Figure 46 The proportional distribution of ED visits by CTAS scale (Canadian Institute for Health Information, 2005).

2.2.3 Seeking Care by Daily Hours Distribution

The first contact in seeking health services for Canadians differs depending on the time of the day. Table 11 shows where Canadians aged 15 and older reported, in 2001, that they were most likely to seek routine care and immediate care for minor health problems for themselves or a family member during regular office hours (9 a.m. to 5 p.m., Monday to Friday), evenings (5 p.m. to 9 p.m.) and weekends and at night (Canadian Institute for Health Information, 2005). Figure 47, however, shows ED visits in 2003-2004 fluctuated over the course of the day. The volume of ED visits increased just after 7:00 a.m. and rose steadily until 11:00 a.m. (Canadian Institute for Health Information, 2005).

Table 11 First contact of Canadians aged 15 and older seeking health services by daily hours distribution (Canadian Institute for Health Information, 2005).

	Routine or Ongoing Care			Immediate Care for Minor Health Problems		
Setting	Regular Hours	Evenings and Weekends	Night	Regular Hours	Evenings and Weekends	Night
Family Doctor's Office	80%	20%	N/A	49%	8%	**
Walk-in Clinic	12%	42%	N/A	23%	34%	1%*
Hospital or Emergency Department	4%	32%	N/A	23%	53%	93%
Community Health Centre	3%	4%*	N/A	4%*	3%*	**
Other	1%*	2%*	N/A	1%*	1%*	**

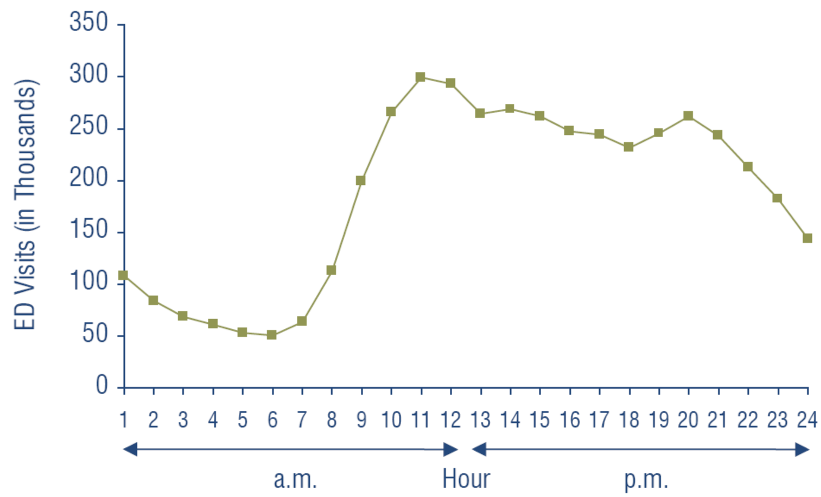


Figure 47 Canadian ED visit distribution over the course of the day (Canadian Institute for Health Information, 2005).

ED visits in the morning increased for lower severity patients in 2003-2004, as shown in Figure 48. Less severe patients categorized as CTAS IV/V (for example, those suffering from sore throat, chronic back pain, or menses) visit the ED more often than patients at a high severe level of CTAS I (who require resuscitation). This distribution impacts the volume variation over the course of the day (Canadian Institute for Health Information, 2005).

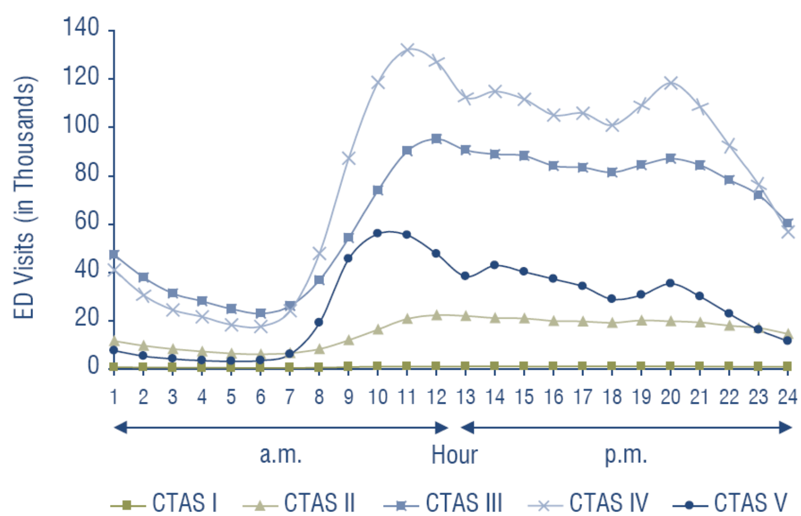


Figure 48 ED visits over the course of the day distributed according CTAS levels (Canadian Institute for Health Information, 2005).

2.2.4 Waiting for ED Care

The Length of Stay (LOS), or the median amount of time spent in the ED, was just over two hours in 2003-2004 and varied by the time of the day, as shown in Figure 49. Morning ED visits had shorter LOS, either because of low influx or hospital staff discharged patients at faster rate than during the rest of the day or night (Canadian Institute for Health Information, 2005).

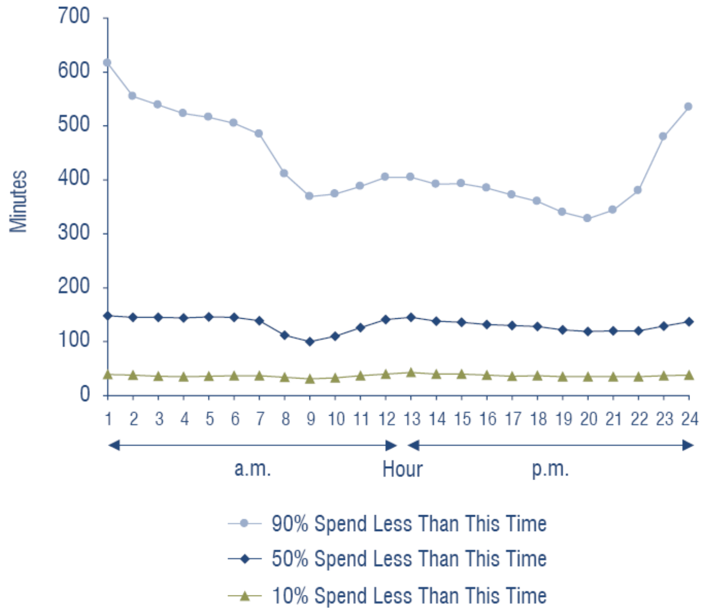


Figure 49 LOS time distributed over the hours of the day (Canadian Institute for Health Information, 2005).

Age also had an effect on the LOS time in 2003-2004. Older patients in the ED had longer LOS than younger ones with no correlation in condition severity level. Figure 50 illustrates patients' distribution per age group and the severity of their illness. LOS includes time spent waiting for initial physician assessment as well as diagnostic tests or procedures and treatments (Canadian Institute for Health Information, 2005).

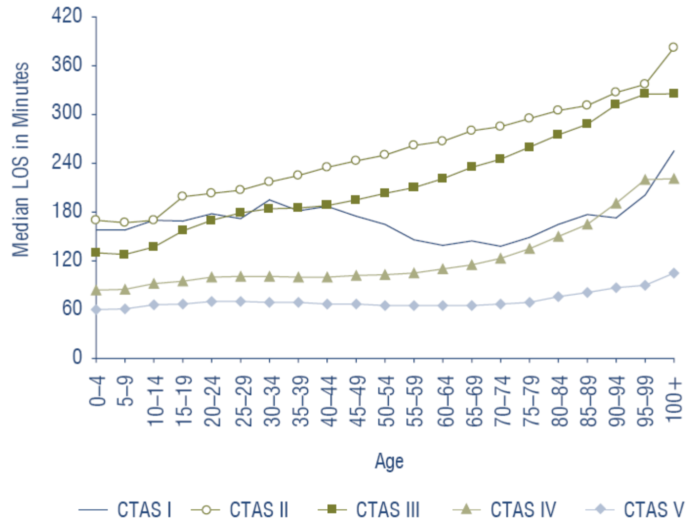


Figure 50 ED LOS over the course of the day distributed according to patients' age (Canadian Institute for Health Information, 2005).

LOS varied according to both severity of illness and the type of ED. In 2003-2004, patients visiting EDs in teaching hospitals had the longest LOS regardless of the severity of their condition, as indicated in Figure 51 (Canadian Institute for Health Information, 2005).

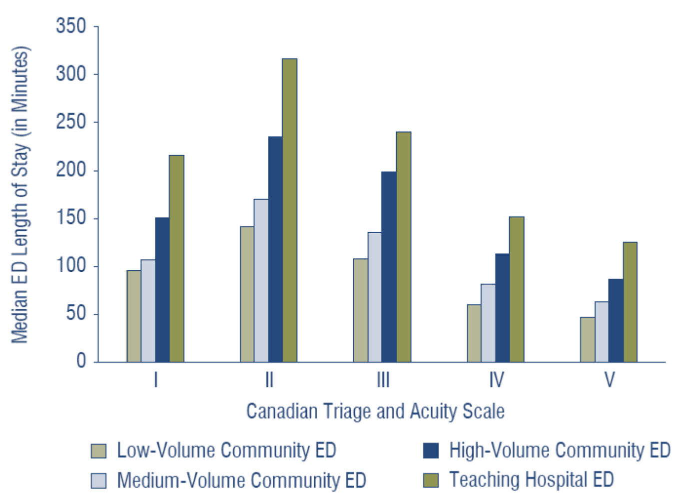


Figure 51 LOS is affected by both severity of illness and type of ED (Canadian Institute for Health Information, 2005).

2.2.1 Waiting for Initial Physician Assessments

The total time spent in EDs, or LOS, consists of two time epoches: the initial time waiting for a physician's examination after registration, and the time spent obtaining treatment for their illness prior to being discharged. The time waiting to see a doctor is an important measure as it influences ED LOS. (Yoon, I. Steiner, 2003). Patients' outcomes are influenced by the time spent waiting for the initial physician assessment, which is an important factor, for some specific conditions (M. J. Schull, 2005). In Ontario, according to The National Ambulatory Care Reporting System data, "patients waited a median time of 51 minutes to be assessed by a physician in 2003–2004. This is the time at which half of patients spent less than this time and the other half spent more than this time. Ten percent of ED patients waited 10 minutes or less (10th percentile), while 10% waited 165 minutes or more (90th percentile). In general, median wait times to see a physician varied slightly by the volume of patients in EDs at the time of the visit, but much more so by patient severity" (Canadian Institute for Health Information, 2005). Figure 52 represents ED LOS in Ontario's newly organized Local Health Integration Networks. Differences in ED LOS may in part be explained by differences in the distribution of illness severity of the patients seen in the Local Health Integration Networks (Canadian Institute for Health Information, 2005).

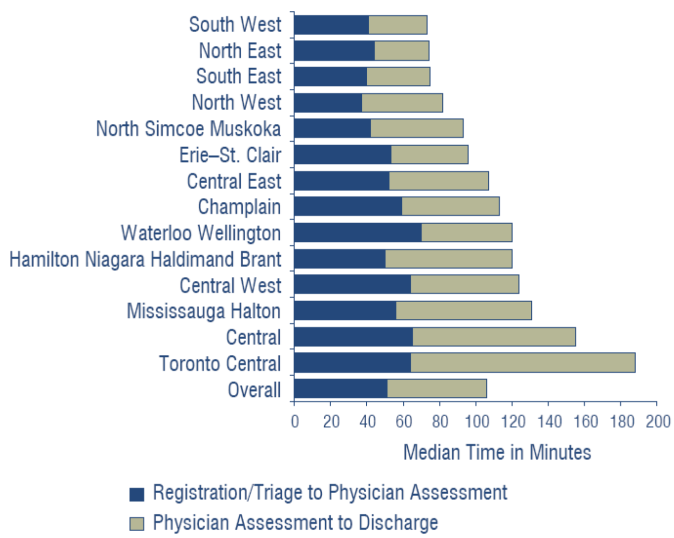


Figure 52 LOS in Local Health Integration Networks represented by two segments: the time from registration (or triage) to being seen by a physician and the time from then until discharge(Canadian Institute for Health Information, 2005).

How soon a patient sees a doctor is another measure of LOS in EDs. Statistics collected in 2003-2004 show that patients see a doctor more quickly if their registration or triage occurs between 7:00 a.m. and 9:00 a.m., despite the increase in patient volumes visiting EDs at this time. Increased number of staff coming on shift contributed to the quicker process time. Figure 53 presents LOS distribution over the daily hours (Canadian Institute for Health Information, 2005).

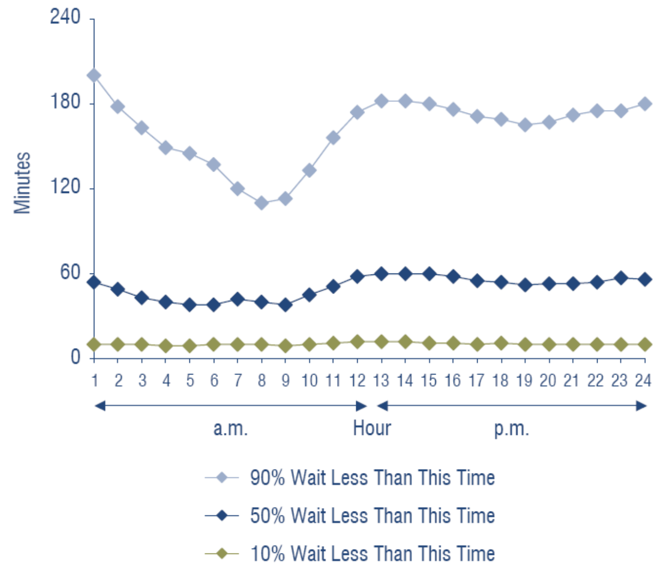


Figure 53 Despite the increase in patients' volumes, the time to see a doctor drops between 7:00 a.m. and 9:00 a.m. (Canadian Institute for Health Information, 2005).

Establishing Goals for Time to Physician Initial Assessment: A physician's primary assessment is critical to some patients, depending on their health conditions. Therefore, when the Canadian Triage and Acuity Scale (CTAS) was established, targeted times for a physician's initial assessment were also developed:

CTAS I Resuscitation: immediate

CTAS II Emergent: 15 minutes

CTAS III Urgent: 30 minutes

CTAS IV Less-Urgent: 60 minutes

CTAS V Non-Urgent: 120 minutes

Although the established times are not standards, they are useful as a baseline for comparing different EDs and assessing performance. "Analyses of the 2003-2004 National Ambulatory Care Reporting System data according to these goals suggest that most patients are seen within these times. But that's not true for everyone. A higher proportion of those triaged as non-urgent (CTAS V) are seen within the proposed time (87% under 120 minutes) than those triaged as most severely ill (54% of CTAS I patients were seen in under 5 minutes). And, 10% of patients in this category waited 45 minutes or more for initial assessment by a physician" (L. F. McCaig and and Burt, 2002).

2.2.2 Discharged From the ED

Patients are discharged from the ED in multiple ways; however, the majority leave to their homes. Furthermore, there are differences between the distribution of patients' discharge in Alberta and Ontario, as shown in Table 12. While

Alberta has a higher percentage of patients who are discharged to their place of residence, Ontario reports a higher proportion of hospitalizations (11%) than Alberta (8%). Differences between the two provinces are also seen in the proportion of patients who Leave Without Being Seen (LWBS) and who leave without medical advice. Different severity level distributions might explain the provincial differences in ED statistics (Canadian Institute for Health Information, 2005).

Table 12 Means by which patients leave EDs, as well as their differing distributions in Alberta and Ontario (Canadian Institute for Health Information, 2005).

	Ontario* (2003–2004)		Alberta (2001–2002)	
Disposition	No.	%	No.	%
Returned to Residence	3,660,900	83.9	1,583,400	87.4
Transfers	28,600	0.7	21,200	1.2
Left Without Being Seen	136,800	3.1	7,200	0.4
Left Against Medical Advice	30,200	0.7	41,600	2.3
Admission to Hospital	475,600	10.9	146,100	8.0
Death	6,500	0.1	1,700	0.1
Other	25,400	0.6	11,100	0.6
Total	4,364,000	100	1,812,300	100

Appendix B: History of ED Practice

The Beginning of Emergency Care

Historically, the appearance of emergency care started in Europe in the Middle Ages. Developed from the need to prioritize and provide immediate care to injured soldiers in battlefield settings, the concept of triage (meaning "to sort") was adopted in France in the early 1800s. Napoleon's chief surgeon recognized the need for quickly evacuating and then treating all the injured in an area close to the front lines. This was done using the first-ever ambulances, which were horse-drawn vehicles that picked up people from the front lines.[7] The Industrial Revolution witnessed the evolution of emergency medicine as more and more people entered the workforce of the industrialized world, and the number of workers suffering accidents, injuries and other health problems increased (G. Fitzgerald, 1998). "The integration of emergency medicine with efficient transportation has been highlighted by the National Academy of Sciences. For example, the excellence of initial first aid, efficiency of transportation and energetic treatment of seriously injured patients have proven to be major factors in the progressive decrease in death rates of battle casualties reaching medical facilities, from 8% in World War I, to 4.5% in World War II, to 2.5% in Korea and to less than 2% in Vietnam."[8] (G. Fitzgerald, 1998)

Emergency Medicine Appearance as a Medical Specialty

"Canada now recognizes emergency medicine as an independent specialty, with professional associations and a structured training program. So do the UK, the U.S., Ireland, Australia, New Zealand and Japan, but not countries such as Germany and France. Until the 1970s, those practising emergency medicine in Canada received little or no formal training in the provision of ED care[10]. In the early 1970s, the Royal College of Physicians and Surgeons of Canada proposed that emergency medicine programs be developed. During the 70s and 80s, groups of physicians formed different organizations to improve the quality of emergency care through specialized education, structure and standards. By 1980, the Canadian Association of Emergency Physicians had been formed and emergency medicine had been approved by the Royal College as a new specialty. In addition, the College of Physicians of Canada (CFPC) established certificates as an incentive for graduates who committed to a career in emergency medicine.

Emergency nursing was also born as a specialty around the same time. In 1980, the Canadian Nurses Association (CNA) began a certification program for specialty nursing groups including specialized roles emerging for working in EDs. Today, care in the ED involves a variety of health professionals, from emergency physicians and nurses to cardiologists, neurologists, vascular surgeons, technicians and others. General and family practitioners (GP/FP) also work in some EDs. In fact, based on the National Physician Survey 2004, a study sponsored by the College of Family Physicians, the Canadian Medical Association, the Royal College of Physicians and Surgeons of Canada and the Canadian Institute for Health Information, almost one quarter (23.5%) of Canada's GP/FPs reported working in EDs in 2003 in some capacity. EDs are also fertile training grounds for many medical residents not planning on specializing in emergency medicine” (G. Carriere, 2004).

Variable Calculations and/or Definitions

Canadian Triage and Acuity Scale (CTAS)
CTAS is one measure of a patient's priority for treatment and an indirect estimator of the symptom severity on arrival to the ED developed by Canadian Association of Emergency Physicians. The urgency, or need for ED treatment, decreases as CTAS scores increase. The CTAS levels used in National Ambulatory Care Reporting System are 1) resuscitation required, 2) emergent care required, 3) urgent care required, 4) less-urgent care required and 5) non-urgent care required.

Emergency Department Length of Stay (EDLOS)
The total time spent by a patient in an emergency department from time of registration or triage (whichever occurs first) to the time of visit completion.

Methodology of Calculation:
EDLOS is calculated as the difference between the start (triage or registration) and the end of the visit in minutes.

Notes:
In cases of visits that lead to hospital admission, discharge time recorded in National Ambulatory Care Reporting System does not necessarily correspond to the patient's actual transfer to the ward or intensive care unit (ICU). When calculating EDLOS, patients who left without being seen were excluded, since their departure time may not always be recorded correctly.

Time to Physician Initial Assessment (Time to PIA)
The time spent by a patient in an emergency department from time of registration or triage (whichever occurs first) to the time of initial physician assessment.

Methodology of Calculation:
Time of either registration or triage, depending which occurs first, is considered as the start of the visit. Time to PIA is calculated as the difference in minutes between the start of the visit and the time of initial physician assessment.

Notes:
Physician initial assessment times were not recorded for patients who left without being seen by a physician or for patients assessed by healthcare providers other than a physician. These records were excluded from the sample. A small number of records where physician assessment time was more than one hour earlier than the start of the visit time were excluded from the analysis due to the high probability of physician initial assessment time being misreported. When the physician's assessment time was less than one hour earlier than the start of the visit, time to PIA was set to zero.

Appendix C

Bimaristan Al-Nouri Overview

Bimaristan Al-Nouri is considered one of the most important historical science buildings in the Syrian capital as it lies in the heart of Damascus in Al-Hariqah area, near the Umayyad mosque. It was built in 1154 AD by Sultan NourAldeenZanki to serve as a hospital and medical school, usually visited by specialists and researchers to benefit from its historical library. In the Ottoman Empire it was transformed into a girls' school before becoming a museum of medical science for the Arabs. It was one of the greatest medical schools in that age in the east and was considered a central hospital with different departments under the supervision of specialized doctors. Bimaristan Al-Nouri was similar to the palaces due to the luxuries it offered, the facilities available and the quality of food given to patients. The medication was for free for both the poor and the rich, as were clothes and money, so that patients could rest at home for two weeks without having to work. In appreciation of this unique construction and the distinctive role it played in developing the medical and pharmaceutical sciences, the directorate general for the antiquities and museums renovated the Bimaristan to become a medical museum for the Arabs. The museum contains four main halls, one for the sciences, the other for the medicine, the third for the pharmacology and the last for the stuffed animals and birds, in addition to a small room that includes a library for specialized science books. It is known that medicine for the Arabs during the Middle Ages was a noble industry with practice limited to one with wide experience, an anatomist, familiar with organ functions, and having great knowledge of all medicine-related sciences.

Source:

http://www.kuna.net.kw/NewsAgenciesPublicSite/ArticleDetails.aspx?Language=en&id=1480941

Appendix D

Output data collected from simulating high severe level patient's process.

Tag	Operation	PID	FILTER	VA	NVA	Data	Data	Data	Data	Data	Data	Data	Data	Data	Data	Data	Data	Data	Data	Data
		pid_1	filter_1	value added	non value added	activity takt time	activity va per item	assoc. time per item	associates	batch size	customer daily demand	cycle time	cycle time per item	inventory	lead time	queue	takt time	total value added	value added percent	wait
				min	day	min	min	min	staff	item	item	min	min	item	day	day	min	min	%	day
A030	Walk in	1.00	1.00		1.00									200.00						
A040	Reception	1.00	1.00	5.00		2.40	5.00	5.00	1.00	1.00		5.00	5.00							
A060	Triage 1	1.00	1.00	5.00		2.40	5.00	5.00	1.00	1.00		5.00	5.00							
A110	Registeration	1.00	1.00	10.00		2.40	10.00	10.00	1.00	1.00		10.00	10.00							
A130	Triage 2	1.00	1.00	20.00		2.40	20.00	20.00	1.00	1.00		20.00	20.00							
A150	Primary Assessment	1.00	1.00	15.00		2.40	15.00	15.00	1.00	1.00		15.00	15.00							
A170	Assessment	1.00	1.00	40.00		2.40	40.00	40.00	1.00	1.00		40.00	40.00							
A190	Symptomatic Treatment	1.00	1.00	30.00		2.40	30.00	30.00	1.00	1.00		30.00	30.00							
A210	ED Order Tests	1.00	1.00	120.00		2.40	120.00	120.00	1.00	1.00		120.00	120.00							
A220	Results Received	1.00	1.00	10.00		2.40	10.00	10.00	1.00	1.00		10.00	10.00							
A230	Review Results	1.00	1.00	5.00		2.40	5.00	5.00	1.00	1.00		5.00	5.00							
A240	Plan of Care	1.00	1.00	5.00		2.40	5.00	5.00	1.00	1.00		5.00	5.00							
A260	Observe	1.00	1.00	720.00		2.40	720.00	720.00	1.00	1.00		720.00	720.00							
A270	Decision to Discharge	1.00	1.00	1.00		2.40	1.00	1.00	1.00	1.00		1.00	1.00							
A290	Prepare Output	1.00	1.00	5.00		2.40	5.00	5.00	1.00	1.00		5.00	5.00							
A300	Discussion with Patient	1.00	1.00	10.00		2.40	10.00	10.00	1.00	1.00		10.00	10.00							
A330	Prepare Output	1.00	1.00	5.00		2.40	5.00	5.00	1.00	1.00		5.00	5.00							
A390	Wait	1.00	1.00		0.00									0.00						
A400	Wait	1.00	1.00		0.00									0.00						
A410	Wait	1.00	1.00		0.00									0.00						
A450	Wait	1.00	1.00		0.00									0.00						
A460	Discharge Patient	1.00	1.00	30.00		2.40	30.00	30.00	1.00	1.00		30.00	30.00							
A470	Prepare room and bed	1.00	1.00	10.00		2.40	10.00	10.00	1.00	1.00		10.00	10.00							
A520	Type	1.00	1.00		0.00									0.00						
A530	Wait	1.00	1.00		0.00															0.00
A540	Wait	1.00	1.00		0.00															0.00
A550	Wait	1.00	1.00		0.01															0.01
A560	Wait	1.00	1.00		0.00															0.00
A570	Queue	1.00	1.00		0.00											0.00				
A590	Wait	1.00	1.00		0.00															0.00
A600	Queue	1.00	1.00		0.00											0.00				
A610	Wait	1.00	1.00		0.00															0.00
A620	Wait	1.00	1.00		0.00															0.00
A630	Queue	1.00	1.00		0.00											0.00				
A650	Wait	1.00	1.00		0.00															0.00
A660	Wait	1.00	1.00		0.00															0.00
A670	Queue	1.00	1.00		0.00											0.00				
A680	Queue	1.00	1.00		0.00											0.00				
A690	Queue	1.00	1.00		0.00											0.00				
A700	Queue	1.00	1.00		0.00											0.00				
Z010	Time Summary		0.00												3.20		2.40	1046.00	68.12	
Z020	Customer		0.00								200.00									
Z030	Outside Source		0.00																	

Appendix E

Output data collected from simulating low severe level patient's process.

Tag	Operation	PID	FILTER	VA	NVA	Data	Data	Data	Data	Data	Data	Data	Data	Data	Data	Data	Data	Data	Data	Data
		pid_1	filter_1	value added	non value added	activity takt time	activity va per item	assoc. time per item	associates	batch size	customer daily demand	cycle time	cycle time per item	inventory	lead time	queue	takt time	total value added	value added percent	wait
				min	day	min	min	min	staff	item	item	min	min	item	day	day	min	min	%	day
A030	Walk in	1.00	1.00		1.00									200.00						
A040	Reception	1.00	1.00	0.00		7.20	0.00	0.00	1.00	1.00		0.00	0.00							
A060	Triage 1	1.00	1.00	0.00		7.20	0.00	0.00	1.00	1.00		0.00	0.00							
A110	Registeration	1.00	1.00	0.00		7.20	0.00	0.00	1.00	1.00		0.00	0.00							
A130	Triage 2	1.00	1.00	5.00		7.20	5.00	5.00	1.00	1.00		5.00	5.00							
A150	Primary Assessment	1.00	1.00	10.00		7.20	10.00	10.00	1.00	1.00		10.00	10.00							
A170	Assessment	1.00	1.00	0.00		7.20	0.00	0.00	1.00	1.00		0.00	0.00							
A190	Symptomatic Treatment	1.00	1.00	0.50		7.20	0.50	0.50	1.00	1.00		0.50	0.50							
A210	ED Order Tests	1.00	1.00	5.00		7.20	5.00	5.00	1.00	1.00		5.00	5.00							
A220	Results Received	1.00	1.00	1.00		7.20	1.00	1.00	1.00	1.00		1.00	1.00							
A230	Review Results	1.00	1.00	0.20		7.20	0.20	0.20	1.00	1.00		0.20	0.20							
A240	Plan of Care	1.00	1.00	0.20		7.20	0.20	0.20	1.00	1.00		0.20	0.20							
A260	Observe	1.00	1.00	0.50		7.20	0.50	0.50	1.00	1.00		0.50	0.50							
A270	Decision to Discharge	1.00	1.00	0.20		7.20	0.20	0.20	1.00	1.00		0.20	0.20							
A290	Prepare Output	1.00	1.00	0.50		7.20	0.50	0.50	1.00	1.00		0.50	0.50							
A300	Discussion with Patient	1.00	1.00	0.50		7.20	0.50	0.50	1.00	1.00		0.50	0.50							
A330	Prepare Output	1.00	1.00	0.50		7.20	0.50	0.50	1.00	1.00		0.50	0.50							
A390	Wait	1.00	1.00		0.00									0.00						
A400	Wait	1.00	1.00		0.00									0.00						
A410	Wait	1.00	1.00		0.00									0.00						
A450	Wait	1.00	1.00		0.00									0.00						
A460	Discharge Patient	1.00	1.00	0.50		7.20	0.50	0.50	1.00	1.00		0.50	0.50							
A470	Prepare room and bed	1.00	1.00	2.00		7.20	2.00	2.00	1.00	1.00		2.00	2.00							
A520	Type	1.00	1.00		0.00									0.00						
A530	Wait	1.00	1.00		0.04															0.04
A540	Wait	1.00	1.00		0.08															0.08
A550	Wait	1.00	1.00		1.00															1.00
A560	Wait	1.00	1.00		0.13															0.13
A570	Queue	1.00	1.00		0.08											0.08				
A590	Wait	1.00	1.00		0.08															0.08
A600	Queue	1.00	1.00		0.06											0.06				
A610	Wait	1.00	1.00		0.08															0.08
A620	Wait	1.00	1.00		0.02															0.02
A630	Queue	1.00	1.00		0.21											0.21				
A650	Wait	1.00	1.00		0.04															0.04
A660	Wait	1.00	1.00		0.04															0.04
A670	Queue	1.00	1.00		0.17											0.17				
A680	Queue	1.00	1.00		0.00											0.00				
A690	Queue	1.00	1.00		0.01											0.01				
A700	Queue	1.00	1.00		0.42											0.42				
Z010	Time Summary		0.00												3.48		7.20	26.60	0.53	
Z020	Customer		0.00								200.00									
Z030	Outside Source		0.00																	