HEALTHCARE FAILURE MODE EFFECT ANALYSIS OF THE PATIENT FLOW IN VICTORIA HOSPITAL

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ABSTRACT

Victoria Hospital is a secondary-level medical facility located in the southern suburbs of Cape Town, South Africa. Victoria Hospital faces a unique set of obstacles linked to vast social and economic disparities. A lack of funding from the Provincial Department of Health prevents Victoria from expanding its facility and investing in new medical technologies and management programs. In order to optimize its current facility and procedures, a healthcare systems engineering approach was taken to improve the quality of care with minimal resource expenditure. A Healthcare Failure Mode Effect Analysis (HFMEA) was performed on the patient flow of Victoria Hospital in order to identify the most critical areas of the hospital for process improvement. The HFMEA followed the patient experience from check-in to the Emergency Department until discharge from the facility by identifying potential failures and their associated risks to the patient population and healthcare providers. Twenty-six of the 47 failure modes were prioritized for corrective action, recommended actions were identified, and a resource investment evaluation was used to illustrate the feasibility of intervention. Many of the most critical failures are associated with capacity and overcrowding issues, particularly in the Emergency Department. Keeping in mind a limited budget, long-term and short-term goals were created. Long-term goals include expanding Victoria Hospital, adding experienced medical and auxiliary staffing, creating a decontamination room, upgrading to Electronic Medical Records, and investing in a bed management system software. In the short term, great strides can be made in Victoria Hospital by hiring a bed manager and a discharge manager, improving check-in procedures, and updating the parking lot for efficient arrival to and exit from the hospital.
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CHAPTER 1

Introduction: Health Care in the Context of South Africa

Only 22 years ago, South Africa underwent radical political and social change with the fall of Apartheid and the establishment of the first constitutional democracy. Apartheid, the Afrikaans word for “the state of being apart,” was a set of legislation enforced under the National Party that strived to establish white dominance and racial segregation [1]. Discrimination pervaded all aspects of South African society and left a clear mark on the country’s healthcare delivery. Separate divisions of health by region and race were established to segregate health services. Vast inequality existed between care provided to urban and rural areas, with the urban areas offering superior technologies, facilities, and professionals to their patients [4]. A private health sector emerged at the expense of the public sector, attracting better resources and a paying population. A three-tiered, uncoordinated system of health was established in 1919 and was reinforced with Health Act No. 63 in 1977, which separated medical facilities into primary, secondary, and tertiary levels of care. As a result, the public sector became even more inefficient and dysfunctional [1].

On April 27, 1994, a new Constitution and Bill of Rights was born in South Africa, which recognized human dignity, equality, and freedom as the foundational values of the country [1]. In the peaceful transition to democracy, the new Constitution underscored the importance of equality in healthcare and laid out the following health-related socioeconomic rights:
• An environment that is not harmful to one’s health or well-being (Section 24)
• Adequate housing (Section 26)
• Healthcare services, including reproductive healthcare (Section 27(1) and (2))
• Emergency medical treatment (Section 27(3))
• Sufficient food (Section 27(1)(b))
• Sufficient water (Section 27(1)(b))
• Social security (Section 27(1)(c))
• Basic nutrition, shelter, healthcare services, and social services for children (Section 28(1)(c))
• Adequate accommodation, nutrition, reading material and medical treatment for incarcerated persons (Section 35(2)(e)) [1]

In addition to the laws established in the Constitution, various acts were also passed that allowed free abortion services in the first 12 weeks of pregnancy, regulation of medicine to make prices more affordable, and all pregnant women and children under the age of six free health services. Ngwena, et al., in Advancing the Human Right to Health, consider the White Paper for the Transformation of the Health System of South Africa the most important policy passed in the healthcare sector because it shifted the focus toward primary healthcare and sought to redistribute healthcare resources [1]. In order to bridge the urban-rural discrepancy, more money was allocated to providing care and building clinics in historically underserved, rural areas. The policy also established the District Health System (DHS) to better organize and dispense health services.
On October 11, 2014, the South African National Department of Health launched their Human Resources and Revitalization Plan to improve healthcare and achieve millennium development goals. The plan employed three streams: primary healthcare (PHC) outreach, school health services, and specialized health [14]. Primary care, or community-based care, was to be strengthened by deploying PHC outreach teams composed of a nurse and several community health workers to screen the population and refer them to appropriate resources. The second part of the mission sought to establish health presence in every school to ensure childhood access to medical care and education in reproductive health and drug use. Finally, health teams were assigned to each of South Africa’s 52 districts to provide specialized attention and address geographic inequalities [14]. While the plan was well intentioned, its success was contingent upon the initiative of district health management and their ability to gather and equip a surplus of healthcare professionals, which it was not prepared to substantiate.

While political and social progress has been made, the legacy of Apartheid has plagued the health and well-being of the nation. Ngwena et al. state that Apartheid has created inequalities in health that have still not been broken despite attempts from legislation and redistribution of resources [1]. Though the economic growth and expansion of the black middle class has reduced absolute poverty over the past 20 years, there has been no significant decrease in relative poverty [1]. South Africa still has the highest global income disparity with a Gini coefficient of 0.68 (2009) [2]. The top 10% of South Africans earn 75% of the total annual national income, while the bottom 70% earn a combined 7%. [15]. Living on two dollars or less per day, about 45% of the South African population is defined as impoverished. More than 10 million people live below the food poverty line of one dollar per day and are unable to sustain an
adequate diet [4]. A close correlation exists between wealth and health. Mayosi et al., in “Health and Health Care in South Africa – 20 Years After Mandela,” note “Health is majorly affected by lack of access to clean water, adequate nutrition, sanitation, suitable housing conditions, vaccinations, schooling, childhood nurturing, and availability of jobs that position one for a life of health and longevity” [4]. Ngwena et al. exemplify this in life expectancy statistics; the African population lives an average of 49.2 years, while the White population lives an average of 63.6 years [1]. Clearly, the economic inequality has led to a large gap in the health and longevity of each racial group, and population health cannot be achieved as long as such vast economic disparities persist. [1,4].

The inconsistency in quality of care between private and public health sectors has also contributed to the inability of South Africa to recover its healthcare delivery. Legislation has been passed to broaden the scope of the private sector and reach more of the population. The introduction of the National Health Insurance pursuant to Section 3 of the National Health Act states that everyone must have access to appropriate, efficient, and quality healthcare services [1]. However, the State contradicts its efforts by granting permission for public sector senior staff to spend a portion of their time in the private sector, thereby undermining the already-inadequate resources and productivity of state-provided care [4]. Public care remains the sole provider for more than 40 million uninsured people – a staggering 84% of the population – and is only staffed by 30% of the doctors in the country. The private sector services the remaining 16% of the population, employing 70% of the professional doctors in the country [4]. The annual per capita expenditure on health ranges from $1400 in the private sector to approximately $140 in the public sector [4]. Mayosi et al. analyze the current state of South Africa’s healthcare and explain
that “many of the state hospitals are in a state of crisis, with much of the public health care infrastructure run down and dysfunctional as a result of underfunding, mismanagement, and neglect” [4]. Echoing Mayosi et al., Ngwena et al. state that “there are many facilities experiencing over-crowding, long waiting periods for patients, shortages of supplies and equipment, poor working conditions, and low staff morale” [1]. Both sources indicate that the disparity in healthcare delivery has not been bridged through the past 20 years of efforts.

In addition to the challenges presented by public and private health discrepancies, South Africa faces the obstacle of providing healthcare to a vast spectrum of inhabitants. The health profile of the nation reflects that of both a deprived, underdeveloped nation and a first-world, thriving nation. The Africa Health Placements (AHP) defines this predicament as the “quadruple burden of disease,” which includes (1) HIV and related diseases; (2) diseases of inequality, poverty, and underdevelopment, notably infectious diseases; (3) chronic disease of lifestyle; and (4) high fatality rate related to injury and violence [14, 1]. South Africa has the highest concentration of people living with HIV, at 5.6 million sufferers, and HIV accounts for 31% of the total deaths in the country [1]. Tuberculosis is another epidemic in the country, accounting for 13% of all deaths [1]. The nation also holds very high mortality rates for infants, children under five, and mothers [1]. While the impoverished, rural population suffers from these conditions, South Africa’s affluent, urban population experiences heart attacks, strokes, and other chronic diseases caused by their own lifestyle choices.

Ngwena et al., Mayosi et al., and the AHP agree that too much emphasis was placed on legislation as a route to improve health, neglecting the complex landscape of the nation’s health
crisis [1, 4, 14]. Ngwena et al. explain, “South Africa’s challenge is no longer about creating a Constitution, policy, and legislation that enable the right to health but rather implementation [1].” Implementation has indeed been the issue for the South African government; legislative reform is one thing, but tangible progress at the hospital level is another. The AHP communicates that the health system is “more crippled than ever” and is in “desperate need of re-evaluation” [14]. In agreement with the AHP, Mayosi et al. areadamant that more efforts must be devoted to the training and managing of healthcare professionals to meet the population’s increasing demand [4]. The ratio of the physicians per 1000 people in South Africa is a mere 0.76. Not only has it failed to increase in the past 10 years, but it is far below that of socioeconomically similar countries like Brazil (1.76 in 2008), Russia (4.31 in 2006), and China (1.46 in 2010) [4]. According to “Health and Health Care in South Africa – 20 Years after Mandela,” South Africa needs at least three times its current health workforce to meet the HIV needs of the population [4].

It is evident that South Africa’s healthcare crisis is deeply embedded in the history and culture of the nation. Vast size and complexity exists in the challenges that accompany redefining the scope of the public sector, addressing the deficit in resources, and servicing a diverse patient population. These goals entail closing a gap of massive disparities, which requires a total economic and social transformation rather than simply hospital optimization. Mayosi et al. insightfully differentiate between long-term and short-term goals, aiming to drive attainable strategies that can make an impact on healthcare delivery here and now. Long-term goals include a fundamental shift in the structure and culture of the entire healthcare system, which will take many years and obstacles to overcome. In the short-term, Mayosi, et al. suggest strengthening
and reengineering current facilities to improve the nation’s healthcare delivery [4]. The article states, “One of the first priorities must be to resuscitate and strengthen existing facilities to strive for high-quality teaching, conditions of service, and an ethos of care in clinical services that, in synergy, could foster the dedication of health care professionals to provide services with excellence, rather than merely seek the security of job and salary [4].” In other words, improving care in pre-existing facilities and boosting the moral and support of current health professionals can make significant progress in quality of care. It urges South Africa’s health administration to “do better with less” [4]. While it would be ideal to build new hospitals throughout the country and staff them with a surplus of healthcare professionals, the country does not have the capacity to fully resource this mission. Critical problem-solving approaches must be applied to existing healthcare delivery models in order to provide optimal improvement with minimal resources. An overall shift in managerial attitude can make substantial progress if hospitals are able to analyze their current systems, identify gaps in health delivery and quality, and implement systematic improvement methodology.

Healthcare systems engineering and healthcare delivery science seek to provide solutions to today’s complex healthcare challenges [6]. Data-driven and mathematical sciences create methods to analyze processes in order to increase efficiency and quality of care [16]. Healthcare systems are inherently complex because patients, care providers, payers, and other stakeholders are variable in behavior and their relationships are nonlinear in nature. A healthcare system has six interconnected levels: the patient, the population, the team, the organization, the network, and the political and economic environment (PPTONE) [16]. Building a Better Delivery System, a report by the National Academy of Engineering (NAE) and Institute of Medicine (IOM),
concluded that the main cause of crisis in safety, quality, cost, and access of the American healthcare system can be explained by complexity [17]. Complex systems require systems thinking to analyze and understand levels of interactions because a system is not the sum of parts, but rather the product of their interactions [6]. Very few systems engineering techniques were applied to health-related fields before the 1950’s and 1960’s, when the first known industrial engineers were hired by hospitals. Since then, healthcare systems engineering has grown from simple process studies to public health policy analysis, evidence-based medicine best practices for treatment strategies, and data mining and analytics to facilitate diagnoses. The 2010 Patient Protection and Affordable Care Act in the United States has placed additional emphasis on quality of healthcare services and patient outcomes, which has further expanded systems engineering tools as they apply to healthcare settings [18]. While the study of healthcare systems engineering is popular in the United States and many other developed nations today, there is little to no research devoted to the unique healthcare challenges facing South Africa [5]. South Africa’s medical facilities are many years behind the advancements and process improvements found in developed nations. Compelling evidence suggests that systems engineering is in accordance with the healthcare goals of South Africa and the key to transformation of its complex delivery system.
CHAPTER 2

Problem Description: Victoria Hospital’s Patient Population and Health Care Delivery

Figure 1: Victoria Hospital Main Entrance

Victoria Hospital, in Wynberg, Cape Town, is experiencing the effects of South Africa’s struggling healthcare system. Victoria Hospital, shown in Figures 1, 2, and 3, is a secondary-level hospital that is estimated to serve over 800,000 people from the city of Cape Town, many coming from disadvantaged or impoverished backgrounds [5]. It acts as the referral center for a district hospital, ten community health centers, and dozens of general practitioners in the region. Victoria offers a broad range of medical services including an emergency department, internal medicine, surgical and sub-surgical specialties, orthopedics, pediatrics, anesthetics, psychiatry, and radiology. Victoria is also a teaching hospital affiliated with The University of Cape Town;
it prides itself on its commitment to training doctors, medical specialists, and allied health professionals [5].

Figure 2: Victoria Hospital Front View

Figure 3: Victoria Hospital Back View

Primary hospitals act as the first level of care, secondary hospitals provide care requiring the intervention of specialists and general practitioners, and tertiary hospitals provide sub-
specialist support for regional hospitals [4]. A secondary, or regional, hospital is designed to accommodate referrals from lower levels of care. Referrals require specialization of personnel, sophistication of diagnostic technologies, and a degree of therapeutic technologies that is not offered at the district level. Hensher et al. and Cullinan conclude that secondary hospitals are often the most overburdened and understaffed in South Africa [23]. This is largely due to the inadequacies of the district, or primary hospitals, which are responsible for providing the community with a range of services, an emergency center, and an operating theater [4]. Referrals should only take place when primary healthcare providers lack the skills, facility, or staff to manage a clinical condition [23]. However, because many of the primary hospitals in South Africa are dysfunctional or inadequate, patients are referred to secondary level hospitals for primary-level conditions. On an aggregate level, this results in inappropriate utilization of higher-level facilities.

According to Hensher et al., patients will also “self-refer” to the highest level of care rather than visiting a district hospital first [23]. Perception of higher quality of care and resource availability, desire to avoid delays in referral, and proximity to the nearest medical facility all influence a patient’s decision to opt out of lower-level care [23]. Self-referral and the inadequacy of district hospitals cause overcrowding of regional facilities and bottlenecks in patient flow. Overcrowding results in delays for patients as relatively simple, more urgent, cases take priority. This is becoming an increasing problem with the rise of HIV cases, which should typically be serviced at the primary level. It also costs the state additional resources because less complex patients are receiving treatment in expensive environments. Hensher et al. indicate that
secondary-level hospitals are typically twice as expensive per bed per day as district hospitals, which can significantly drain state resources if not properly utilized [23].

Perhaps Victoria’s greatest burden is its size; the facility is much too small for the population it serves. Victoria Hospital, built in 1888, is the second-oldest hospital in South Africa [5]. One-hundred twenty-eight years ago, the hospital was designed as a 38 bed unit, and it has grown into a busy, 158 bed district hospital servicing the largest sub-district in the city of Cape Town [5]. The hospital’s limited size directly contributes to overcrowding and inefficient patient flow. Figure 4 below shows Victoria Hospital’s hallway crowded with patients awaiting service [5]. Emergent patients are triaged in the Emergency Department, which is a small room consisting of about 15 beds stacked side-by-side [5]. The Emergency Department serves an estimated 80,000 patients each year, and its demand is so great that the average patient must wait six to eight hours for an available bed [5]. The department will frequently add extra trolleys and place them in the hallway in order to accommodate demand during peak hours.

Figure 4: Overcrowding in Victoria Hospital Hallway
The Department of Medicine suffers greatly from a chronic shortage of beds, as well. As the busiest specialist department in the hospital, this department admits 15-20 patients a day and is responsible for 60-70% of all hospital admissions [5]. There are 58 medical beds distributed across two medical wards for males and females. The bed occupancy of the Department of Medicine is 130%, the extra 30% accommodated by adding extra trolleys in the wards [5]. When there are no available beds in the medical wards, the patients must await an opening by occupying a bed in the Emergency Department, which disables the doctors from seeing more emergent patients. In an interview with Dr. Nasief, a senior specialist doctor in the Department of Medicine, he explained that on Mondays there is often up to 20 patients in the Emergency Department waiting for a bed in a medical ward, which means the flow of patients through the ER comes to a complete standstill [5].

There is also a lack of beds in the Intensive Care Unit (ICU), which can only accommodate three patients at a time. Often patients requiring intensive care are admitted to an inpatient ward due to bed unavailability in the ICU [5]. These patients negatively affect the efficiency of the Department of Medicine because they consume many resources and attention of the doctor and nursing staff. The problem of overcrowding is felt throughout the entire hospital through ambulance diversions, delays in elective surgical admissions, and suboptimal patient care.

A lack of staffing and experience is yet another obstacle Victoria Hospital faces when handling their patient population. An average of 12 doctors are found in the hospital during the week, but an average of only three doctors are staffed over the weekend. Therefore, doctor
service rates become a bottleneck to patient throughput during the weekends, which affects operations early in the week [5]. The hospital also has a limited number of senior doctors, who can see patients quicker and make better decisions. Senior doctors also have the keen ability to identify patients to be transferred to another facility early into the patient’s hospital visit. Less experienced doctors often take longer to refer patients, which bogs down patient flow, increases patient length of stay, and adversely affects patient health [5]. The longer a patient is in the hospital, the more likely the patient will acquire a complication or infectious disease [5]. Longer patient stays also contribute to overcrowding and slowed patient flow. The seniority of nursing staff similarly affects patient outcomes. In addition, the hospital faces the challenge of limited hospital workers such as administrative staff, radiologists, social workers, physical therapists, cleaners, and transporters [5]. Each staff member is necessary for quality health delivery and smooth transition throughout the hospital.

Victoria Hospital must serve a complicated patient population. South Africa’s large wealth gap has created a health profile resembling that of a developed country blended with an impoverished country. Health providers in South Africa call this the “quadruple burden of disease,” which includes HIV/AIDS, diseases of inequality and poverty, chronic disease of lifestyle, and injury caused by violence [1]. Victoria Hospital must be prepared to handle patients with complex and interconnected diseases of lifestyle and infection. Patients often have a combination of diseases, which makes the diagnosis and treatment process exponentially more difficult [5]. It is common for senior doctors, junior doctors, and interns to visit patients in teams in order to consult each other during complicated diagnoses. Because there is less overall education and access to healthcare in Africa, the African population takes longer to seek medical
attention, so patients’ conditions are often very progressed when they finally arrive to the Emergency Department [5]. As these patients take longer to treat, they contribute to a decreased bed turnover rate.

Victoria Hospital also receives a large number of psychiatric patients, which continues to grow each year with the increase abuse of “Tik,” or Methamphetamine. The use of this drug has exploded in the Western Cape over the last ten years because it is inexpensive, widely available, and easy to make [7]. It is highly addictive and leads to the development of acute psychosis. When these “Tik” users arrive to the Emergency Department, it takes many doctors and nurses to stabilize the patients [5]. Because Victoria was not designed to serve psychiatric patients, this greatly impacts the efficiency of the hospital and absorbs much of the staff’s attention [5].

Finally, South Africa experiences the burden of medical tourism from neighboring African countries like Zimbabwe, Botswana, Namibia, and Mozambique [5]. Not only must South African care providers service their native patient population, but they also assume the responsibility to treat patients from countries that lack necessary medical technology. This has also caused a considerable strain on the capacity of Victoria Hospital.

From an administrative standpoint, Victoria Hospital experiences many obstacles with management. Victoria faces chronic underfunding by the Western Cape Provincial Department of Health, which prevents the facility from investing in current, or up-to-date, administrative resources. The hospital does not have a bed management system, or bed manager, to maintain the flow of patients, discharge activities, and managerial issues that affect staff productivity [5]. In
Victoria, the nursing staff primarily performs the bed manager roles, which can be particularly stressful and managerially complex because of the lack of beds in the Emergency Ward, Medical Wards, and ICU.

In addition, Victoria still uses paper medical records. Past paper medical records are more difficult to store and access than electronic medical records (EMR), which becomes a problem with reoccurring patients in the ER. Paper medical records can also be more difficult to read and interpret, further debilitating hospital efficiency and accuracy. Victoria Hospital faces intranet connectivity and system errors more frequently than hospitals in developed nations. South Africa experiences load shedding, the deliberate shutdown of electrical power as a means to reduce the demand of energy generation. When Victoria’s district experiences load shedding, generators supply the hospital with power, but there is a possibility of delay or failure [5]. Any one or combination of administrative errors can greatly inhibit Victoria’s effective health delivery.

The vision of Victoria hospital aligns with the Western Cape Provincial Department of Health to provide “equal access to quality health care.” Victoria prides itself in a strong commitment and passion demonstrated by its staff and volunteers to improve the healthcare of all its patients [1]. Unfortunately, many obstacles prevent Victoria from providing the quality of healthcare they aspire to deliver to the patient population of Cape Town. Victoria has an inefficient and inhibited patient flow, which leads to unnecessary process steps, delays, and jeopardized safety. Though many other hospitals in South Africa experience similar challenges in their facilities, there are very few studies dedicated to the nation’s healthcare delivery. Healthcare systems engineering is a booming discipline in developed nations, which approaches
the industry as a complex system and applies engineering design and analysis principles to
improve efficiency and quality of care [6]. A surplus of patient flow improvement studies
saturate research, but very few are applicable to the resource limitations and unique
circumstances that Victoria faces. Victoria Hospital is in need of a systems engineering approach
to process improvement that requires minimal resources while providing maximum benefits to
patient health and organizational impact.
CHAPTER 3

Analysis Methodology

Victoria Hospital faces unique obstacles in providing quality healthcare to its patient population. Overcrowding, insufficient staffing, complex patient profiles, and administrative complications inhibit smooth and efficient flow from patient arrival to discharge within the facility. Patient flow is the process by which patients move through a hospital system and transition between healthcare settings [19]. A smooth patient flow is indicative of a well-functioning hospital with favorable provider-to-patient ratios, few delays and cancellations, and a high level of safety and quality of care [6]. Disruptions to patient flow may be minor and rather undisruptive, or quite serious and detrimental to the health and safety of the patients and healthcare providers. I contend that healthcare systems engineering methodology and process improvement tools may be used to analyze and optimize the patient flow of Victoria Hospital.

FMEA Methodology

Failure Mode Effect Analysis (FMEA) is a systematic approach to identify all possible failures in a design, a manufacturing or assembly process, or a product or service. “Failure modes” are the ways a process might fail, and “effect analysis” refers to the studying of the consequences of these failures and prioritizing according to how serious they are, how frequently they occur, and how easily they can be detected [3]. According to Tague in The Quality Toolbox, the purpose of a FMEA is to eliminate or reduce failures by starting with prioritized items first.
and to document current knowledge and actions about the risks of failures [3]. Traditionally, an associated severity, occurrence, and detection factor for each failure mode enables the analyst to calculate a Risk Priority Number (RPN) to determine intervention priority. The failure modes with the highest RPNs are considered the highest priority areas of the system, and corrective action eliminates these failures first. After corrective action, a new RPN is calculated to gauge and report the improvement in the system. The FMEA is quite suited to Victoria Hospital because it allows the evaluators to determine the most critical problems in the hospital that are perhaps impacting the most patients and healthcare providers. The tool recognizes that not all areas of the process can be optimized, but perhaps corrective action of the most severe failures can make significant strides toward better health outcomes. This means that, given the limited resources in South Africa’s public healthcare system, Victoria Hospital may operate optimally within their means. Additional benefits of FMEA include increasing customer satisfaction and safety, capturing engineering and organizational knowledge, and providing a catalyst for teamwork and idea exchange between functions [8].

The first step in conducting a FMEA is assembling a cross-functional team of three or four people, each from disciplines that have different views of the product or process under investigation. FMEA requires a cross-functional team in order to create a collaborative basis for people in different areas of a process to work together for overall organizational improvement. A cross-functional team may also be necessary to eliminate inherent biases. After the team is assembled, the topic and scope of the FMEA is identified by assessing the objectives of the project and qualifications of the team [3]. Next, a flow diagram is used to graphically describe the process by assigning each process step a number that corresponds with the FMEA chart. A
FMEA chart is typically executed in Microsoft Excel or similar software; an example appears below in Figure 5 [20].

![FMEA chart](image)

**Figure 5. Traditional Failure Mode Effect Analysis Format**

In the first column titled *Item/Function*, each process step is listed from the flow diagram with its corresponding number. The next two columns explain each failure mode that may occur during a process step and the effects of each failure, respectively. A severity rating (S) is given on a scale of 1 to 10, where 1 is insignificant and 10 is catastrophic. Next, the root cause of the failure is noted, and a probability rating (O) is assigned to the cause from 1 to 10, where 1 is unlikely and 10 is inevitable. The current process controls, or ways to detect failure, are then identified. The detection rating (D) occurs in the following column, where 1 means the control is certain and 10 indicates the control is not certain. Finally, the RPN is calculated by multiplying S x O x D for each failure mode. The team collaborates to assign responsibility, recommended actions, and set target completion dates for each failure mode. The highest RPN values are given priority in completion tasks and timeline. After the failure mode has been addressed with corrective action, the team records the actions, and assigns a new RPN, accordingly [3].
**HFMEA Methodology**

FMEA was developed by the US Military in the 1940’s and later spread to aviation, nuclear power, aerospace, chemical, and automotive applications [21]. Historically, accident prevention was not a primary focus of hospital medicine, as there was a misguided reliance on “faultless” performance by healthcare professionals. It was not until the early 1990’s that FMEA began to be a viable process improvement tool in healthcare. Effective in 2001, it became a recommended tool by The Joint Commission on Accreditation of Healthcare Organizations (JCAHO) Standard LD.5.2 to define and implement an ongoing proactive program for identifying risks to patient safety and reducing medical errors [21].

As a result of the increased interest in continuous process improvement tools for healthcare applications, The Healthcare Failure Mode and Effects Analysis (HFMEA) was designed by the Veterans Affairs National Center for Patient Safety (NCPS) specifically for healthcare. The HFMEA combines the detectability and criticality steps of the traditional FMEA into an algorithm presented as a decision tree. The RPN is replaced by a hazard score, which is simply the product of the severity and probability rating [21]. Guidelines for severity and probability ratings are clearly defined for healthcare applications in tables, and range from 1 to 4 instead of 1 to 10. A Hazard Matrix Table is also used to decide which failure modes will receive priority for process improvement.

Process steps for performing a HFMEA are similar to a traditional FMEA. NCPS identifies the first step as defining the topic with a clear definition of the process to be studied. Next, a multidisciplinary team is assembled including subject matter experts and an advisor. The
process is to be graphically described by a flow diagram, with each process step numbered. Next, the *Hazard Analysis* is performed, which includes listing all possible/potential failure modes and effects of the failure modes for the process steps identified in the flow diagram [22]. The NCPS defines a hazard analysis as “the process of collecting and evaluating information on hazards associated with the selected process,” and its purpose is “to develop a list of hazards that are of such significance that they are reasonably likely to cause injury or illness if not effectively controlled” [22]. A severity rating is assigned to the effect using the Severity Rating Table, a modified version of the NCPS Severity Rating Table appears in Table 1.

![Table 1: Severity Rating Table](image-url)

<table>
<thead>
<tr>
<th>OUTCOME</th>
<th>SEVERITY RATING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient</td>
<td>Death or major permanent loss of function (sensory, motor, physiologic, or intellectual), suicide, rape, hemolytic transfusion reaction, surgery/procedure on wrong patient or wrong body part, infant abduction or infant discharged to wrong family</td>
</tr>
<tr>
<td>Visitor</td>
<td>Death or hospitalization of 3 or more visitors</td>
</tr>
<tr>
<td>Staff</td>
<td>Death or hospitalization of three or more staff</td>
</tr>
<tr>
<td>Equipment or Facility</td>
<td>Damage equal to or more than $250,000</td>
</tr>
<tr>
<td>Fire</td>
<td>Any fire that grows larger than incipient/beginning stage</td>
</tr>
</tbody>
</table>
The potential causes of each failure mode and their corresponding probability ratings are determined. A modified NCPS Probability Rating Table appears in Table 2.

<table>
<thead>
<tr>
<th>Probability</th>
<th>Frequent – 4</th>
<th>Occasional – 3</th>
<th>Uncommon – 2</th>
<th>Remote - 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Likely to occur immediately or within a short period (may happen several times in one year)</td>
<td>Probability will occur (may happen several times in 1 to 2 years)</td>
<td>Possible to occur (may happen sometime in 2 to 5 years)</td>
<td>Unlikely to occur (may happen sometime in 5 to 30 years)</td>
</tr>
</tbody>
</table>

A hazard score is determined for each failure mode by multiplying the probability score by the severity score. A modified NCPS Hazard Decision Matrix, shown in Table 3, illustrates the relationship between probability and severity, and may be used to identify the hazard score. The greyed boxes are used to flag hazard scores of 8 or higher for concern.

<table>
<thead>
<tr>
<th>Probability</th>
<th>Frequent</th>
<th>Occasional</th>
<th>Uncommon</th>
<th>Remote</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severity of Effect</td>
<td>Catastrophic</td>
<td>Major</td>
<td>Moderate</td>
<td>Minor</td>
</tr>
<tr>
<td>Frequent</td>
<td>16</td>
<td>12</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Occasional</td>
<td>12</td>
<td>9</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Uncommon</td>
<td>8</td>
<td>6</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Remote</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Then, the decision tree is used to determine whether or not the failure mode warrants corrective action. By following the logic of the decision tree, a failure mode receives review if it has a hazard score of 8 or higher [22]. The decision tree also requires the analyst to determine if the failure mode is a single point failure. A single point failure is defined as a part of a system that will disable the entire system from operating if failure were to occur [25]. The decision tree
requires the verification of an Effective Control Measure, which the NCPS defines as “a barrier that eliminates or substantially reduces the likelihood of a hazardous event occurring” [22]. An Effective Control Measure is not needed if the hazard is obvious or readily apparent, also noted by the decision tree. The failure mode will either reach “Stop,” meaning the analysis indicated that it does not warrant corrective action, or “Proceed” in order to continue with actions and outcome measures. A modified version of the HFMEA Decision Tree created by the NCPS is shown in Figure 6.

Figure 6: HFMEA Decision Tree
Following the decision tree analysis, the actions and outcome measures are defined for each failure mode that resulted in “Proceed” by the decision tree. The analysis team must complete the Actions and Outcome Measures portion of the HFMEA table with the appropriate information for documentation purposes. Finally, the Results portion of the HFMEA table is updated after corrective action has taken place.

**Process Improvement Methodology for Victoria Hospital Patient Flow**

I chose NCPS HFMEA as the process improvement methodology for the patient flow of Victoria Hospital. Although different HFMEA models exist, I followed the methodology and formatting of the NCPS HFMEA model. The NCPS designed the original HFMEA and its structure is most widely used in health systems engineering application. I concluded the HFMEA model was best suited for the patient flow analysis because it provides a streamline procedure for process improvement in a medical facility. The metrics for assigning severity and probability ratings are clearly defined for healthcare scenarios, which prevents subjectivity and inconsistency in rating. Additionally, a hazard matrix and decision tree assist in determining intervention priority rather than merely RPN.

In the case of Victoria Hospital, I used this tool to analyze every step of a patient’s experience in the hospital in order to holistically understand and document current knowledge of patient flow, identify the problems that may occur, and understand how those problems affect the quality of care or safety of patients and care providers. I developed a flow chart for each item of patient flow to ensure each step in the process was analyzed for potential failure. Then, I
replicated each step of the patient flow in the HFMEA, so that the hazard analysis began when
the patient arrived on the hospital premise and ended when the patient exited the hospital
premise. Finally, I used the decision tree to decide if the failure mode warranted actions and
result measurements.

While the analysis closely followed the framework the NCPS defined for the HFMEA, I
made several modifications to make the model more applicable to Victoria Hospital’s unique
healthcare scenario. The HFMEA table provided by the NCPS lists the failure modes in the left-
most column without listing the process steps first. I chose to list each step in the patient flow
process in the first column to correspond to the flow chart, and then identify the failure mode
associated with each process step in the second column. I also decided to list the Potential
Effects of Failure, unlike the NCPS HFMEA, in order to better consider the severity rating of
each failure mode. In addition, I modified the Actions and Outcomes portion of the HFMEA
table because I will not be involved for the changes and implementations portion of the patient
flow improvement process. I added a Recommended Actions column in order to provide Victoria
Hospital with proposed solutions to the given failure mode. I allocated a space for the hospital to
assign a date for each failure mode intervention to aid in planning, as well as assign new severity
ratings, probability ratings, and hazard scores after corrective action has taken place. This will
allow the facility to better document their hazard score reduction and track their improvement in
the future. Finally, I modified the Probability Rating Table to better encompass the scope of the
failure modes occurring in Victoria Hospital. The probability ratings still range from 1 to 4, but
the frequency of occurrence defining each rating increased dramatically by replacing years with
weeks. Using the following Probability Rating Table, shown in Figure 10, I identified each failure mode’s probability score.

### Table 4: Victoria Hospital Probability Rating Table

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequent – 4</td>
<td>Likely to occur immediately or within a short period (may happen several times in one week)</td>
</tr>
<tr>
<td>Occasional – 3</td>
<td>Probability will occur (may happen several times in 1 to 2 weeks)</td>
</tr>
<tr>
<td>Uncommon – 2</td>
<td>Possible to occur (may happen sometime in 2 to 5 weeks)</td>
</tr>
<tr>
<td>Remote - 1</td>
<td>Unlikely to occur (may happen sometime in 5 to 30 weeks)</td>
</tr>
</tbody>
</table>

With these modifications, I performed a NCPS HFMEA to better define and analyze the patient flow of Victoria Hospital. Following the completion of the HFMEA, the responsibility to implement the recommended improvements falls back upon Victoria Hospital. Recommended actions were proposed in the HFMEA tool, but a team of hospital experts is best suited to develop actions and outcome measures based upon the intervention priority identified in the HFMEA. The tool is designed to be constantly updated to monitor Victoria’s progress.

**Analysis Team**

As previously stated, a cross-functional team is essential to perform a proper HFMEA. A core team of three to four people typically conducts a FMEA with additional subject matter experts. The team is comprised of individuals from disciplines with slightly different views on the process to create a powerful synergy in analysis [24]. Upper-level management and members from different levels of the organization work together in order to gain insightful perspectives. Failure to have a variety of representation on the team is likely to result in skewed conclusions and the absence of process components or potential risks [3]. For the purposes of this project, I
sought a team member with vast knowledge about Victoria Hospital and South African healthcare, as well as an expert in systems engineering and process improvement tools as they pertain to healthcare. The team that joined me to perform the FMEA of Victoria Hospital consists of Dr. Nasief, Dr. Kilinc, and Dr. Nembhard.

I was responsible for the research and data collection portion of the project. From literature and consultations with Dr. Nasief, Dr. Kilinc, and Dr. Nembhard, I accurately collected the information and compiled the results into deliverables. I spent the past four years studying system and process improvement methodology for the completion of a Bachelor of Science in Industrial Engineering at The Pennsylvania State University. My education gave me the expertise to perform the HFMEA with the direction of participating doctors. As a full-time student, I possessed the willingness and time to dedicate to the project’s success. I provided a third-party perspective, but first-hand account of the daily activity and processes of Victoria, as I shadowed Dr. Nasief and gathered preliminary data and observations for four months while studying at The University of Cape Town. This compelled me to initiate the project because I was able to experience the massive challenges and great demand on Victoria’s healthcare delivery system. I spent a total of six months in South Africa and during this time, I learned a great deal about the culture and history of the nation. It was a unique opportunity for an undergraduate student, and I believe it positioned me to perform an insightful analysis.

Dr. Nasief has been the primary specialist in the Department of Medicine in Victoria for over 10 years, and he is a teaching doctor at the University of Cape Town. Not only is he very knowledgeable about patient flow and bed management, but he is also a subject-matter expert in
the procedures and performance requirements of Victoria. He is the necessary link to personnel inside the hospital that provided insights into the unique challenges of Victoria Hospital and South African healthcare delivery. As one of the top, most respected doctors in the facility, Dr. Nasief has the ability to hand off the analysis to upper-level management and propose implementation of the results. In addition, Dr. Nasief works with other physicians, nurses, and administrative staff that have unique perspectives on process failures and recommendations. Dr. Nasief is in the position to rally the support and participation of many key staff members in the hospital. Perhaps most importantly, Dr. Nasief is passionate about providing exceptional quality care to his patients. He dedicates his life to serving the people of Cape Town and teaching aspiring doctors at The University of Cape Town.

Dr. Harriet Nembhard is a Professor of Industrial Engineering and Director of the Center for Integrated Healthcare Delivery Systems at The Pennsylvania State University. Dr. Nembhard served as my thesis supervisor for the duration of the project. Her research focus is healthcare systems engineering, an area which she has published over 20 journal articles and co-authored a textbook titled Healthcare Systems Engineering. She is an expert in process improvement methodology in the healthcare delivery setting, and she offered to apply her knowledge to the patient flow challenges of Victoria Hospital along with Dr. Nasief and myself. Dr. Kilinc, a postdoctoral researcher in the Center for Integrated Healthcare Delivery Systems, also has experience utilizing analysis tools and compiling deliverables for implementation in other healthcare settings, which was valuable to the success of this project. South Africa has not invested in the breadth of systems engineering techniques available in the United States, so literature and comparative studies do not exist. However, Dr. Nembhard and Dr. Kilinc bridged
that gap and provided expertise to a hospital that would otherwise not have had the chance to participate in a process improvement project.

Overall, all necessary roles in the team were fulfilled: Dr. Nasief offered expertise and access to Victoria Hospital and South African healthcare management, Dr. Nembhard and Dr. Kilinc are experts in systems engineering and process improvement tools in the healthcare setting, and I was a liaison to compile and draft the analysis and deliverables. The entire team possessed the willingness and availability to complete the HFMEA, thus meeting the team collaboration criteria.

Success Criteria

The HFMEA tool was designed to streamline patient flow with the mission of improving the quality of care and working toward the organizational goals of Victoria Hospital. As Victoria proceeds with improvement initiatives, its staff must evaluate the success of its actions by validating improved patient health and organizational implications.

Quality of Care

I expect an improvement in the quality of care provided to the patients of Victoria Hospital given the implementation of a patient flow HFMEA. Several factors describing a patient’s experience in a hospital can indicated the quality of hospital care and predict patient outcomes. Factors influencing overall quality of care include patient wait time, patient length of stay, and provider-to-patient time. I expect the analysis and proper implementation of its recommendations to positively affect all three factors.
Wait time is the length of time between the moment a patient arrives at the hospital to the moment the patient is serviced in the Emergency Department. The Emergency Department works hard to ensure very sick patients are seen first and that all patients are seen in a timely manner. However, overcrowding and capacity constraints lead to very long wait times – an average of six to eight hours in Victoria [5]. The timeliness of care can greatly impact health outcomes. In general, a longer wait time results in negative health outcomes. The study, “Impact of Emergency Department Crowding on Outcomes of Admitted Patients,” published by the Annals of Emergency Medicine, found that high levels of Emergency Department crowding lead to a five percent higher chance of death in the hospital [9]. Long wait times allow complications to develop in a patient’s condition. HFMEA seeks to decrease the door-to-provider time because it eliminates inefficiencies and streamlines the patient experience.

The length of stay for this project is defined as the time between the patient’s entry into the Emergency Department and discharge from the hospital. Victoria Hospital has a unique set of circumstances that threaten patient health including the presence of infectious diseases, overcrowded departments, and fewer sanitation precautions. According to Dr. Nasief, the longer a patient remains in the hospital, the greater the chance that the patient acquires a health complication [5]. Patricia Stone, centennial professor of health policy at Columbia Nursing, stated “Reducing length of stay is the holy grail of hospital management because it means patients are getting higher quality, more cost-effective care” [11]. To avoid jeopardizing patient health, Victoria hospital must minimize length of stay for its patients. HFMEA seeks to decrease
patient length of stay by preventing failures that disrupt the continuous flow of patient care from service to discharge.

Provider-to-patient time refers to the amount of individualized care a patient receives during his or her course of stay. The time physicians and nurses spend with the patient involves gathering information about the patient, monitoring their state, and treating the patient for the appropriate diagnosis. It is largely accepted that more provider attentiveness to the patient is positively correlated with better health outcomes. More attention on the patient reduces the risk for medical errors and increases the likelihood of catching the onset of complications. The provider-to-patient time is expected to increase as a result of the implementation of the analysis recommendations. Physicians and nurses have many demands on their time besides direct patient care including hunting supplies, tracking medication, completing paperwork at the nursing station, looking for test results, and managing beds. By eliminating process bottlenecks and improving the efficiency of patient flow, the likelihood of care providers performing extraneous activities will diminish. With less time consumed troubleshooting errors and more time available addressing patient needs, I expect health outcomes for the patients in Victoria Hospital to improve.

Overall, the quality of care is expected to improve due to the HFMEA on the hospital’s patient flow. The wait time and length of stay will decrease as process efficiency increases. Provider-to-patient time and attentiveness are expected to improve as care providers’ schedules consist of less extraneous tasks and more bedside care. The success of the HFMEA is dependent, and may be measured, by quality of care.
Organizational Impact

A successful HFMEA will have positive organizational impacts on Victoria Hospital and the Provincial Department of Health. For the purposes of this report, the evaluation factors used to determine positive or negative organizational impact includes staff morale and execution of mission.

According to the Merriam-Webster dictionary, morale is defined as the enthusiasm, confidence, or loyalty of an individual or group with regard to a function or task at hand [12]. In a hospital setting, staff morale refers to the satisfaction of doctors, nurses, and staff with their jobs, and the sense of commitment they have to serving the patient population. Stresses in medical facilities are high, employee shifts are often long, and the work is physically, emotionally, and mentally draining. Significance is placed on maintaining high levels of staff morale because high demand is placed on hospital employees, and their performance is critical to the success of its healthcare delivery. Suitable work environments and conditions are directly correlated to high staff morale. Matthew McHugh, an Assistant Professor of Nursing at the University of Pennsylvania, performed a study showing that good work environments for nurses lead to better patient care [13]. According to Barbra Balik, co-author of IHI white paper titled *Achieving an Exceptional Patient and Family Experience of Inpatient Hospital Care*, “When you fully engage with staff and providers, you get that commitment to the organization at a deep and powerful level, and that’s when you get results” [13]. In other words, the level of emotional commitment and engagement of the hospital staff is expected to greatly impact Victoria Hospital and the quality of care it is able to provide. Currently, Victoria Hospital staff is responsible for troubleshooting problems and managing patient transfers. Improvement in patient flow will
affect staff by eliminating unnecessary tasks and alleviating the burden of process errors. HFMEA strives to increase staff satisfaction and create a better work environment by streamlining operations and elevating risks.

The vision and the mission of Victoria Hospital align with the Western Cape Provincial Department of Health. The hospital’s vision is to provide “equal access to quality health care,” underpinned by a strong commitment and passion demonstrated by all staff and volunteers employed at the hospital [1]. Its mission is to “improve the healthcare of all its patients, by ensuring the provision of a balanced health care system, in partnership with all stakeholders, within the context of optimal socio-economic development” [1]. The decisions made by the Department of Health and Victoria Hospital are steered by these values. Process improvement and engineering initiatives will impact the hospital in a way that upholds its ideals and improves the quality and accessibility of health to its patient population. Few healthcare systems studies are applicable to the resource limitations and unique circumstances of Victoria Hospital, so the project is a valuable asset to not only the hospital, but also the Department of Health as they aim to improve other preexisting medical facilities. The analysis will identify weaknesses in patient flow and develop a platform for continuous improvement. The accessibility of care will broaden to a greater patient population because the throughput and efficiency of patient flow will increase, allowing the facility to care for more patients. Overall, an HFMEA of the patient flow in Victoria Hospital helps both of these organizations fulfill their mission. As a result of a HFMEA of Victoria Hospital, overall organizational impact will be achieved through improvement in staff morale and fulfillment of its mission.
CHAPTER 4

Results

I developed a flow chart and HFMEA table to analyze the patient flow of Victoria Hospital. I also performed a resource investment evaluation in order to provide insightful conclusions and realistic recommendations for future improvement.

Flow Chart

In order to perform a thorough HFMEA, I first developed a flow chart to describe the patient experience in Victoria Hospital from arrival to discharge. The flow chart serves the purpose of defining each step in the patient flow process. I created the flow chart based on observations I made in Victoria Hospital and my general understanding of common hospital procedures. After several revisions, Dr. Nasief reviewed and approved the flow chart of the facility’s patient flow, found in Appendix A.

HFMEA Table

A total of 24 itemized steps were defined for the patient flow process in Victoria Hospital. These process steps serve as the first column of the HFMEA table in the Item/Function column. Next, the Hazard Analysis was performed in order to calculate a final hazard score for each failure mode. I developed Potential Failure Modes through hospital observations and the expertise of Dr. Nasief on the procedures performed in the hospital. Collaboration of the analysis team and literature review led to defining the Potential Effects of Failure column. I determined the severity rating by using of the HFMEA Severity Rating Table, developed by the NCPS and
found in Table 1. The analysis team again pinned down and reviewed *Potential Cause(s)/Mechanism(s) of Failure*. Dr. Nasief defined the probability rating with the use of the modified HFMEA Probability Rating Table in Table 4. The hazard score was found by multiplying the severity and probability ratings. Succeeding the *Hazard Analysis*, the decision tree helped me determine if the failure mode would proceed with corrective action. I identified single point failures, control measures, and detectability through review of medical literature and consultation with Dr. Nasief. Next, I researched and developed *Recommended Actions* for the failure modes that flagged necessary action. I left additional blank spaces for Victoria Hospital to define responsibilities, target completion date, and outcome measures. An additional *Results* portion of the HFMEA table was included for Victoria Hospital to track their actions and new hazard scores. The complete HFMEA of the patient flow of Victoria Hospital can be found in Appendix B.

The HFMEA of the patient flow in Victoria Hospital flagged 26 of the 47 failure modes for corrective action through the hazard analysis and decision tree process. The failure modes that proceeded through the actions and outcome measures of the analysis appear in Table 5 in order of descending hazard score. I was able to identify two major trends from the list of flagged failure modes. First, of the identified failure modes, 56% of the hazard scores were attributed to capacity and overcrowding issues. Nearly 50% of the complete list of failure modes was linked to capacity constraints. Secondly, the Emergency Department is responsible for 50% of the hazard scores linked to a “proceed” failure mode, and 51% of the total failure modes. Of the 22 failure modes identified during the emergency department portion of the patient flow, 15 warranted corrective action.
Table 5. HFMEA Results: Failure Modes to Proceed with Action

<table>
<thead>
<tr>
<th>Item</th>
<th>Failure Mode</th>
<th>Hazard Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Patient waits a long time for triage</td>
<td>16</td>
</tr>
<tr>
<td>7</td>
<td>Patient waits a long time for a bed</td>
<td>16</td>
</tr>
<tr>
<td>8/11</td>
<td>Patient is assigned a bed in close proximity to TB or contagious patient</td>
<td>16</td>
</tr>
<tr>
<td>20</td>
<td>Inappropriate decision to discharge patient</td>
<td>16</td>
</tr>
<tr>
<td>13</td>
<td>Patient waits a long time to be service by nurse or staff</td>
<td>12</td>
</tr>
<tr>
<td>15</td>
<td>Patient is boarded in current department</td>
<td>12</td>
</tr>
<tr>
<td>20</td>
<td>Patient does not understand doctor discharge instructions</td>
<td>12</td>
</tr>
<tr>
<td>15</td>
<td>Patient is admitted to a different, sub-optimal department</td>
<td>9</td>
</tr>
<tr>
<td>16</td>
<td>Required equipment unavailable</td>
<td>9</td>
</tr>
<tr>
<td>1</td>
<td>Patient abandons hospital</td>
<td>8</td>
</tr>
<tr>
<td>1</td>
<td>Patient waits for available parking space</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>Patient abandons hospital</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>Patient abandons hospital</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>Patient abandons hospital</td>
<td>8</td>
</tr>
<tr>
<td>6</td>
<td>Inaccurate assessment of patient condition</td>
<td>8</td>
</tr>
<tr>
<td>7</td>
<td>Patient abandons hospital</td>
<td>8</td>
</tr>
<tr>
<td>9</td>
<td>Ambulance diverted</td>
<td>8</td>
</tr>
<tr>
<td>13</td>
<td>Patient abandons hospital</td>
<td>8</td>
</tr>
<tr>
<td>13</td>
<td>Misdiagnosis</td>
<td>8</td>
</tr>
<tr>
<td>14</td>
<td>Delay in receiving test results</td>
<td>8</td>
</tr>
<tr>
<td>21</td>
<td>Delay in obtaining a social worker</td>
<td>8</td>
</tr>
<tr>
<td>22</td>
<td>Delay in filling prescriptions</td>
<td>8</td>
</tr>
<tr>
<td>23</td>
<td>Family and/or friends are not notified of discharge</td>
<td>8</td>
</tr>
<tr>
<td>5/12</td>
<td>File is lost</td>
<td>6</td>
</tr>
</tbody>
</table>

Resource Investment Evaluation

In order to illustrate the implications of the HFMEA, I performed a resource investment evaluation. In identifying recommended actions for each flagged failure mode, I was able to consider the costs of addressing each failure mode and how each correction would affect the overall system. Cost is considered the combination and interaction of several resource investments such as money, hospital staff, auxiliary staff, engineering, and equipment or facility.
Using the Resource Investment Rating Table found in Table 6, I assigned estimates to each flagged failure mode.

**Table 6: Resource Investment Rating Table**

<table>
<thead>
<tr>
<th>Resource</th>
<th>Major Investment 4</th>
<th>Moderate Investment 3</th>
<th>Minor Investment 2</th>
<th>Minimal Investment 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Money</td>
<td>More than $1,000,000 initial investment with substantial subsequent costs</td>
<td>$100,000 - $1,000,000 initial investment with minimal subsequent costs</td>
<td>$10,000-$100,000 initial investment</td>
<td>$10,000 or less initial investment</td>
</tr>
<tr>
<td>Hospital Staff</td>
<td>Addition of 2 or more senior doctors, 4 or more junior doctors, or 8 or more nursing staff</td>
<td>Addition of 1 senior doctor, 2-3 junior doctors, or 5-7 nursing staff</td>
<td>Addition of 1 junior doctor or 3 – 4 nursing staff</td>
<td>Addition of 1-2 nursing staff</td>
</tr>
<tr>
<td>Auxiliary Staff</td>
<td>Addition of 20 or more auxiliary staff</td>
<td>Addition of 13 – 19 auxiliary staff</td>
<td>Addition of 5–13 auxiliary staff</td>
<td>Addition of 1 – 4 auxiliary staff</td>
</tr>
<tr>
<td>Engineering</td>
<td>Multi-level project/analysis; Team of 5 or more engineers; Lasting greater than 1 year</td>
<td>Singular objective project/analysis; Team of 2-4 engineers; Lasting 5 – 11 months</td>
<td>Relatively narrow project scope; 1 engineer; lasting 4 months or less</td>
<td>No engineering engagement required</td>
</tr>
<tr>
<td>Equipment or Facility</td>
<td>Equipment costing more than $1,000,000</td>
<td>Equipment costing between $100,000 and $1,000,000</td>
<td>Equipment costing between $10,000 and $100,000</td>
<td>Equipment costing less than $10,000</td>
</tr>
</tbody>
</table>

Through research and estimation, each failure mode received a rating of 1 to 4, 4 signifying the most costly investment and 1 signifying a minimal investment. A summary of each priority failure mode and its corresponding resource investment rating is in Table 7.

The relationship between hazard score and resource requirement rating is illustrated by the chart in Figure 7. It shows that, 55% of the accumulated hazard scores were assigned a resource requirement rating of 4, 15% of hazard scores were assigned a resource requirement of 3, 10% were assigned a resource requirement rating of 2, and 20% were assigned a resource requirement rating of a 1.
<table>
<thead>
<tr>
<th>Item</th>
<th>Failure Mode to Proceed with Action</th>
<th>Resource Investment Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Patient abandons hospital</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>Patient waits for available parking space</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Patient abandons hospital</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Patient abandons hospital</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Patient waits a long time for triage</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Patient abandons hospital</td>
<td>4</td>
</tr>
<tr>
<td>5 (12)</td>
<td>File is lost</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>Inaccurate assessment of patient condition</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Patient waits a long time for a bed</td>
<td>4</td>
</tr>
<tr>
<td>7</td>
<td>Patient abandons hospital</td>
<td>4</td>
</tr>
<tr>
<td>8 (11)</td>
<td>Patient is assigned a bed in close proximity to TB or contagious patient</td>
<td>4</td>
</tr>
<tr>
<td>9</td>
<td>Ambulance diverted</td>
<td>4</td>
</tr>
<tr>
<td>13</td>
<td>Patient waits a long time to be service by nurse or staff</td>
<td>4</td>
</tr>
<tr>
<td>13</td>
<td>Patient abandons hospital</td>
<td>4</td>
</tr>
<tr>
<td>13</td>
<td>Misdiagnosis</td>
<td>3</td>
</tr>
<tr>
<td>14</td>
<td>Delay in receiving test results</td>
<td>2</td>
</tr>
<tr>
<td>15</td>
<td>Patient is boarded in current department</td>
<td>4</td>
</tr>
<tr>
<td>15</td>
<td>Patient is admitted to a different, sub-optimal department</td>
<td>4</td>
</tr>
<tr>
<td>16</td>
<td>Required equipment unavailable</td>
<td>1 – 4</td>
</tr>
<tr>
<td>20</td>
<td>Inappropriate decision to discharge patient</td>
<td>4</td>
</tr>
<tr>
<td>20</td>
<td>Patient does not understand doctor discharge instructions</td>
<td>1</td>
</tr>
<tr>
<td>21</td>
<td>Delay in obtaining a social worker</td>
<td>3</td>
</tr>
<tr>
<td>22</td>
<td>Delay in filling prescriptions</td>
<td>3</td>
</tr>
<tr>
<td>23</td>
<td>Family and/or friends are not notified of discharge</td>
<td>1</td>
</tr>
</tbody>
</table>
From the resource requirement evaluation, it is evident that a majority of the actions to improve the patient flow in Victoria Hospital will require major investments in money, staff, engineering, equipment, and facility. However, if failure modes with resource investment ratings of 1 or 2 are corrected, 30% of the hazard scores associated with priority failure modes will be eliminated. This includes nine out of the 26 failure modes flagged for corrective action.
CHAPTER 5
Conclusions and Recommendations

Conclusions

Healthcare delivery in South Africa is plagued with a legacy of inequality. Even with the abolishment of Apartheid in 1994, the health sector is still in a state of crisis as vast economic disparities define the gap in population health. Victoria Hospital is a public referral hospital servicing a primarily impoverished patient population of 800,000 from the city of Cape Town. Built 128 years ago, Victoria is the second oldest hospital in South Africa and has grown from a 38 to 158-bed unit. It suffers from capacity and overcrowding issues on a daily basis, as Emergency Department wait times of six to eight hours and bed occupancy of 130% are common occurrences. Additional factors including a diverse patient profile, lack of EMR system, and poor bed management practices are additional obstacles Victoria Hospital must overcome.

Victoria Hospital is in need of healthcare systems engineering in order to improve the quality and efficiency of their healthcare delivery. With limited resources and funding, optimization of existing facilities and practices may be the most effective means of improvement. HFMEA is a collaborative, step-by-step approach to document and analyze current processes in order to determine intervention priority and subsequent corrective action in healthcare delivery systems. It seeks to capture engineering and organizational knowledge and provide a catalyst for process improvement. HFMEA, designed by the NCPS, requires
documentation of a process and a hazard analysis, which collects and evaluates information on potential failures and associated significance based on their likelihood to cause injury if not effectively controlled. Severity rating tables and probability rating tables provide parameters to determine a hazard score for each failure mode. Next, a decision tree is utilized to evaluate if the failure mode warrants the development of actions and outcome measures.

The analysis team, consisting of Dr. Nasief, Dr. Nembhard, Dr. Kilinc, and myself, performed a HFMEA on the patient flow of Victoria Hospital. A smooth, efficient patient flow is indicative of a well-functioning hospital with high levels of safety and quality of care. Possible disruptions to the patient flow provide insight into health and safety concerns of a medical facility. Therefore, a HFMEA of the patient flow in Victoria Hospital is a valuable process improvement tool to identify and prioritize potential failures and develop an action plan to address these hazards. A thorough HFMEA of the patient flow in the Emergency Department and Department of Medicine revealed 24 process steps and 47 potential failure modes. Twenty-six failure modes were flagged for corrective action through the hazard analysis and decision tree. A subsequent resource investment evaluation sought to illustrate the implications of correction of these failure modes. I created a Resource Investment Rating Table to estimate the required cost of taking corrective action.

First, the results of the HFMEA revealed serious overcrowding and capacity problems in Victoria Hospital. Failure modes including “patient waits a long time for triage,” “patient waits a long time for a bed,” “patient boarded in current department,” and “patient is admitted to a different, sub-optimal department” accounted for the highest hazard scores, indicating capacity
and overcrowding issues in the facility. In fact, 56% of the hazard scores flagged for corrective action are attributed to capacity and overcrowding issues and 19 of the 47 total failure modes in the HFMEA table. It is evident that capacity and staffing resources must be added to Victoria hospital in order to sustain a smooth and efficient patient flow.

The second major conclusion from the results is the inadequacy of the Emergency Department. Fifty percent of all hazard scores flagged for corrective action were associated with the Emergency Department. Long wait times, overcrowding, close proximity to contagious patients, ambulance diversions, and boarding all link back to the deficiencies of the Emergency Department, and mainly its capacity issues. I identified 22 failure modes for the Emergency Department, and flagged 15 of them for corrective action. The HFMEA certainly revealed Victoria’s vital need for a larger ED with increased capacity and resources.

The resource investment evaluation is a critical link between the recommended actions for improvement and feasibility. Perhaps the greatest struggle facing medical facilities in South Africa is the expansive deficit in resource and funding to provide quality health services. Medical facilities like Victoria are met with the challenge of improving their healthcare delivery at minimal costs. Investment in the newest technology and complete renovation of existing facilities is not a feasible option, but HFMEA and resource evaluation helped to identify critical areas of the hospital that may be corrected with minimal investment. The analysis revealed that 30% of the total hazard scores could be corrected with minimal to minor investment, as defined by the Resource Investment Rating Table in Table 6. Ten percent of hazard scores received a rating of 2 and 20% received a rating of 1. For Victoria Hospital, this means that a third of their
hazards may be eliminated or greatly reduced within their means if resources are properly allocated. Failure modes including parking, ED check-in, discharge instructions, and communication between staff and patient family and friends received large hazard scores of 8 or above, but require minimal resources in money, hospital staff, auxiliary staff, engineering, equipment, and facility.

Both long-term and short-term goals are established for Victoria Hospital. In the long term, a new, updated facility is necessary as the population of Cape Town and medical tourism to the region continues to grow. Its facility is already experiencing critical overcrowding issues, and it is likely to worsen in the following years. Additional hospital staff, including senior doctors, junior doctors, and nurses, is required to offer the highest quality of care. Electronic medical records, a decontamination room, and a bed management system are updates in medical technology that would greatly improve the healthcare delivery of Victoria. As previously noted, these improvements are accompanied by high price tags, and sizeable recognition and investment from the government is necessary to accomplish these goals.

For example, the implementation of electronic medical records received a resource evaluation rating of a 4, indicating the highest level of investment. This endeavor would require the addition of computers in each of the wards and an on-site EMR deployment or web-based, Software as a Service (SaaS) deployment, which first year total cost ownership estimates abut $160,000 [26]. The hospital network and security will most likely need to be updated for successful installation. Following installation, an implementation team is needed to coordinate staff training and workflow redesign procedures to accommodate the new system [27]. In
addition, all paper medical records must be converted to their equivalent electronic version.

Updating from paper to electronic medical records is a large endeavor requiring vast accumulative engineering, staff, equipment, and monetary investment.

In the short term, Victoria Hospital may strengthen their processes and improve their patient care by optimizing their current facility and systems. Large expenditures on new facilities and technologies are outside the realm of possibility in the near future, but systems engineering and optimization of pinch points in patient flow are capable of making great strides toward better healthcare delivery. Priority may be set on flagged failure modes receiving a resource investment rating of a 1 or 2, indicating minimal to minor resource investment. The resource investment evaluation revealed that 30% of the hazard scores were linked to resource ratings of a 1 or 2, meaning these failures could be addressed with a relatively small budget.

I believe the greatest impact could be made by the introduction of a bed manager. A bed manager is responsible for the allocation and provision of beds, which is especially beneficial in hospitals where beds are a scarce resource. A majority of medical facilities in the United States have a bed management system, which controls and optimizes the distribution of beds in different wards of the hospital. Since Victoria is financially unable to invest in a bed management system, a bed manager may be a feasible alternative and reasonable expenditure that could help reduce boarding and curtail long wait times in the Emergency Department. Additionally, Victoria currently moves their beds at night so the most critical patients are situated near the nursing station to receive more immediate attention. A bed manager could oversee that patients are stationed in areas of the ward according to severity at the onset of
admittance, so nurses can spend less time on bed management and more time engaging in
provider-to-patient care.

Hospital bed management systems also oversee discharge activities to ensure all
necessary players are aware of a patient’s discharge procedures for efficient exit from the
hospital and bed turnover. I propose that Victoria Hospital also invest in a discharge manager,
someone responsible for coordinating the discharge procedures for each patient in the
Department of Medicine and Emergency Department. Approximately 25% of the failure modes
identified for the HFMEA were associated with discharge procedures or coordination issues. The
discharge manager would be responsible for issuing discharge procedures to each patient,
communicating with family and friends for transportation, and coordinating with social workers,
pharmacy, and/or other step-up or step-down facilities on the patients’ behalf. Currently, if a
patient is discharged by doctor orders during morning rounds, he or she is usually not out the
doors until evening. By streamlining this process, I expect bed turnover rate to increase, thereby
allowing Victoria Hospital to accommodate more patients.

An HFMEA tool has been provided to Victoria Hospital through a collaborative effort of
Dr. Nasief, Dr. Kilinc, Dr. Nembhard, and myself, but actual implementation and improvement
is now in the hands of Victoria’s administration and staff. HFMEA provides a framework and
platform for process improvement by identifying the most critical or feasible areas of the hospital
to focus resources and efforts. Now, Victoria Hospital must implement these findings if it is to
improve the efficiency and quality of its healthcare delivery. Three to four recommended actions
for each flagged failure mode are identified in the HFMEA table, but additional brainstorming
and collaboration will take place between hospital staff to ensure an optimal action plan is
developed. Once action has taken place, Victoria Hospital will document its improvements and calculate new hazard scores so the HFMEA becomes an ongoing process improvement tool. Only through proper utilization of the HFMEA tool will Victoria see successful outcomes. In Chapter 3, success criteria were defined as patient health and organizational impact. The HFMEA tool has been designed to streamline patient flow with the mission of improving the quality of care and working toward the organizational goals of Victoria Hospital. As Victoria proceeds with improvement initiatives, its staff must evaluate the success of its actions by validating improved patient health and organizational implications. Action will only be taken if both criteria are met with certainty.

**Recommendations**

Additional health systems engineering initiatives will continue to benefit the Emergency Department and Department of Medicine in Victoria Hospital. Minimal research was performed to understand and evaluate the impact of psychiatric patients on the Emergency Department and the rest of the facility. Victoria was never intended to be a psychiatric facility, but increase drug use in the community has led to large influxes of psychiatric patients. These patients consume more time and care from medical personnel to stabilize and diagnosis the extent of their condition. Currently, they receive emergent care in the same department as non-psychiatric patients, and regular nursing staff and doctors are responsible for both types of patients. Separate medical wards and specialized staff may be allocated to psychiatric patients to improve patient
outcomes, but further research and analysis will help consider how this affects the patient flow and hospital management.

Future consideration can be taken to evaluate and develop better means of transportation to and from the hospital and communities of Victoria’s patient population. As previously noted, Victoria Hospital serves primarily impoverished patients, many of whom do not have means of transportation. Presently, the ambulances for Victoria Hospital pick up non-emergent patients and take home patients who do not have another method of transportation. Consequently, ambulances are overburdened and patients may experience long wait times for service. However, delay in ambulance pick-up in an emergent situation may result in serious degradation of patient health or death. An alternative method of transportation is necessary for non-emergent patients so ambulances are able to provide prompt service to emergent cases only.

Finally, future research and analysis can be aimed toward other departments in Victoria Hospital. Victoria Hospital is comprised of six specialty groups: Gynecology, Medicine, Orthopedics, Pediatrics, Psychiatry, and Surgery. Dr. Nasief is the specialist in the Department of Medicine and it experiences 60% to 70% of all admissions to the hospital, so we focused our HFMEA on the patient flow through the ED to the internal medical wards only. However, optimization of other departments would result in more thorough process improvement and optimal results in healthcare delivery. The second largest department in the hospital is the Surgery Department, which accounts for 29% of all admissions, followed by Pediatrics which accounts for 13%. Next steps including an HFMEA tool for both the Surgery and Pediatrics specialty groups will make a more widespread impact on the quality of care in Victoria.
Victoria Hospital has dedicated itself to providing healthcare to the citizens of Cape Town since 1888. Through massive changes in social, economic, and political conditions in the country, Victoria continues to pride itself in quality care, but various obstacles including an increasing and diverse patient profile, insufficient resources and technology, and capacity and funding constraints have formed a strain on its healthcare delivery model. A thorough HFMEA of the patient flow aims to provide a platform for the hospital to operate efficiently within their means and develop an action plan for future improvement. The tool has provided a range of short-term and long-term goals and a methodology for continuous evaluation of its medical practices. I believe that healthcare systems engineering can make huge strides for Victoria Hospital and equip these healthcare providers to improve patient health for the inhabitants of Cape Town. Victoria Hospital has the ability to lead not only the local community toward better health outcomes, but also South Africa’s entire healthcare delivery system toward engagement in engineering initiatives for the transformation of the nation’s health profile.
APPENDIX A

Flow Chart of Victoria Hospital Patient Flow
# APPENDIX B

## HFMEA Victoria Hospital Patient Flow

**Health Failure Mode and Effects Analysis**

**Victoria Hospital**

### Team

- **System:** Patient Flow
- **Location:** Wynberg, South Africa
- **Team:** Kelly Gagnon, Dr. Nasief Van der Schyff, Dr. Harriet Nembhard

### FMEA Details

- **FMEA Date:** 1/25/16
- **Revision Date:**
- **Page:** 1 of 6

### Patient Flow Hazard Analysis

<table>
<thead>
<tr>
<th>Item/Function</th>
<th>Potential Failure Mode(s)</th>
<th>Potential Effect(s) of Failure</th>
<th>Severity</th>
<th>Potential Cause(s)/Mechanism(s) of Failure</th>
<th>Probability</th>
<th>Hazard Score</th>
<th>Decision Tree</th>
<th>Actions and Outcome Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Patient arrives via private transport</td>
<td>Patient abandons hospital</td>
<td>Patient condition continues to exist and/or worsens</td>
<td>4</td>
<td>No available parking; Insufficient signs or indications of parking/ED entrance</td>
<td>2</td>
<td>8</td>
<td>Y</td>
<td>N</td>
</tr>
</tbody>
</table>

### Comments

- **New Severity:**
- **New Probability:**
- **New Hazard Score:**
<table>
<thead>
<tr>
<th>Event Description</th>
<th>Cause</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient waits for available parking space</td>
<td>Patient condition worsens; Congestion in parking lot</td>
<td>Directional signs at hospital entrance and arrows identifying ED; Clearly marked reserved parking spots for emergent patients</td>
</tr>
<tr>
<td>Patient parks in wrong parking space</td>
<td>Ambulance entrance blocked; Staff/Visitor parking occupied</td>
<td>Patient enters through wrong entrance delays servicing and check-in</td>
</tr>
<tr>
<td>(2) Patient enters hospital through wrong entrance</td>
<td>Delay in servicing patient; Patient wandering in hospital</td>
<td>Patient is unable to fill out paperwork delays paperwork completion</td>
</tr>
<tr>
<td>Patient abandons hospital</td>
<td>Patient condition continues to exist and/or worsens</td>
<td>Patient is unable to fill out paperwork delays paperwork completion</td>
</tr>
<tr>
<td>(3) Patient checks-in with ED clerk and completes preliminary paperwork</td>
<td>Another person accompanying patient fills out paperwork on their behalf; Paperwork is filled out later in the patient flow process</td>
<td>Patient cannot find ED entrance or ED check-in delays paperwork completion</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cause</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insufficient signs or indications of parking/ED entrance</td>
<td>Hospital staff or security at entrance to guide patient flow</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cause</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insufficient signage to indicate ED entrance and check-in</td>
<td>Hospital staff or security at entrance to guide patient flow</td>
</tr>
</tbody>
</table>

**Legend:**
- **Y**: Yes
- **N**: No
<table>
<thead>
<tr>
<th>Event Description</th>
<th>Condition Continues to Exist and/or Worsens</th>
<th>ED Clerk Not Staffed or Unavailable; Check-in Queue</th>
<th>Long Queue; Full Waiting Room; Insufficient ED Staffing</th>
<th>Hallway Congestion; Patient Discomfort</th>
<th>File is Lost</th>
<th>Delay in Patient Care Until File is Found; Inappropriate Diagnosis or Treatment May Be Serviced</th>
<th>Increase or Improve ED Clerk Staffing</th>
<th>Increase or Improve ED Clerk Staffing</th>
<th>Expand Waiting Area; Increase/improve ED Staff; Improve Operational Efficiency</th>
<th>Increase/improve ED Staffing; Improve Operational Efficiency of Triage Procedure</th>
<th>Move to EMR; Improve Organization of Records</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient abandons hospital</td>
<td>Patient condition continues to exist and/or worsens</td>
<td>4</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Patient waits for check-in</td>
<td>Patient condition worsens</td>
<td>2</td>
<td>2</td>
<td>8</td>
<td>4</td>
<td>2</td>
<td>Y  N  N  Y</td>
<td>Increase or improve ED clerk staffing</td>
<td>Increase or improve ED clerk staffing</td>
<td>Increase or improve ED clerk staffing</td>
<td>Increase or improve ED clerk staffing</td>
</tr>
<tr>
<td>(4) Patient enters queue to be triaged</td>
<td>Patient abandons hospital</td>
<td>4</td>
<td>2</td>
<td>8</td>
<td>4</td>
<td>2</td>
<td>Y  N  N  Y</td>
<td>Increase or improve ED clerk staffing</td>
<td>Increase or improve ED clerk staffing</td>
<td>Increase or improve ED clerk staffing</td>
<td>Increase or improve ED clerk staffing</td>
</tr>
<tr>
<td>Patient waits a long time for triage</td>
<td>Patient condition worsens; Medical staff does not have proper time to service patient</td>
<td>4</td>
<td>2</td>
<td>8</td>
<td>4</td>
<td>2</td>
<td>Y  N  N  Y</td>
<td>Increase or improve ED clerk staffing</td>
<td>Increase or improve ED clerk staffing</td>
<td>Increase or improve ED clerk staffing</td>
<td>Increase or improve ED clerk staffing</td>
</tr>
<tr>
<td>Patient must sit on floor or wait in hallway</td>
<td>Full waiting room</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>N  N  N  N</td>
<td>Increase or improve ED clerk staffing</td>
<td>Increase or improve ED clerk staffing</td>
<td>Increase or improve ED clerk staffing</td>
<td>Increase or improve ED clerk staffing</td>
</tr>
</tbody>
</table>
(6) Patient is triaged
Inaccurate assessment of patient condition
Inappropriate treatment is serviced to the patient; Patient’s condition may worsen
4 Insufficient/inexperienced staff
2 Assign experienced nurses to triage; increase/improve staffing

(7) Patient enters queue to receive a bed in ED
Patient enters queue to receive a bed in ED
Patient enters queue to receive a bed in ED
4 Long queue; full waiting room; Insufficient ED staffing
2 Expand waiting area; Increase/improve ED staff; Improve operational efficiency

Patient waits a long time for a bed
Patient waits a long time for a bed
Patient waits a long time for a bed
4 Long queue; Insufficient ED staffing
4 Increase/improve ED staffing; Improve operational efficiency; Create a triage procedure before receiving bed in ED

Patient must sit on floor or wait in hallway
Patient must sit on floor or wait in hallway
Patient must sit on floor or wait in hallway
1 Full waiting room
2 Hallway congestion; Patient discomfort

(8) Patient receives a bed in ED
Patient is assigned an extra trolley in hallway
Hallway congestion; Patient discomfort and lack of privacy
1 No bed availability in ED
3 Hallway congestion; Patient discomfort

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>2</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>3</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Event</td>
<td>Patient is assigned a bed in close proximity to TB or contagious patient</td>
<td>Patient contracts TB or contagious disease</td>
<td>Lack of decontamination room, ability to detect infectious patient before exposure, and separate ED for contagious patients</td>
<td>Construct a decontamination room; Create a separate emergency room for potential contagious patients; Determine a more thorough procedure for identifying contagious patients upon ED check-in</td>
</tr>
<tr>
<td>-------</td>
<td>---------------------------------------------------------------------------</td>
<td>------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>(9) Patient arrives via ambulance</td>
<td>Ambulance diverted</td>
<td>Patient must be transported to another facility; Patient condition may worsen</td>
<td>Overcrowding of ED; no available beds</td>
<td>Increase capacity of ED and other wards in hospital; Improve operational efficiency of hospital</td>
</tr>
<tr>
<td></td>
<td>Ambulance entrance is blocked</td>
<td>Difficulty transporting patient to ED; Delay in servicing patients</td>
<td>Insufficient parking signs; Visitor ignorance</td>
<td></td>
</tr>
<tr>
<td>(10) Patient is transported via emergency staff through ambulance entrance to ED</td>
<td>Emergency staff is delayed in transporting patient to ED</td>
<td>Delay in servicing patient which may cause condition to worsen</td>
<td>Hallway congestion of people and additional trolleys; Insufficient staffing</td>
<td></td>
</tr>
<tr>
<td>(11)</td>
<td>Patient receives a bed in ED</td>
<td>Patient is assigned an extra trolley in hallway</td>
<td>Hallway congestion; Patent discomfort and lack of privacy</td>
<td>1</td>
</tr>
<tr>
<td>(12)</td>
<td>Patient's medical records are retrieved</td>
<td>File is lost</td>
<td>Delay in patient care until file is found; Inappropriate diagnosis or treatment may be serviced</td>
<td>3</td>
</tr>
<tr>
<td>(13)</td>
<td>Patient is serviced by nursing staff and doctors</td>
<td>Patient abandons hospital</td>
<td>Patient condition continues to exist and/or worsens</td>
<td>4</td>
</tr>
<tr>
<td>Misdiagnosis</td>
<td>Increases patient's length of stay; Unnecessary treatment and service provided; Patient condition may worsen</td>
<td>4</td>
<td>Inexperience d staff; Complicated or unusual patient</td>
<td>2</td>
</tr>
</tbody>
</table>
|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|-----|---|---|---|---|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------
<p>| Patient waits a long time to be serviced by nurse or staff | Patient condition may worsen; Patient pain and/or discomfort; Bed occupied too long | 3 | Presence of psychiatric patients or very emergent, complicated patients; Overcrowding during peak hours | 4 | <strong>12</strong> | Y | N | N | Y | Increase/improve staffing; Expand hospital capacity; create separate procedures and staff for psychiatric patients and prison patients; Improve operational efficiency |
| <strong>(14)</strong> Necessary tests are ordered | Increases length of stay of patient; Unnecessary work is performed to produce test results | 2 | Inexperience d staff; Complicated or unusual patient | 1 | <strong>2</strong> | Y | N | Y | N |
| Delay in sending test order to test department | Delay in patient test and service; Bed occupied longer than necessary | 2 | Internet connectivity down or too slow | 2 | <strong>4</strong> | N | N | N | N |</p>
<table>
<thead>
<tr>
<th>Event</th>
<th>Effect</th>
<th>Countermeasure</th>
<th>Countermeasure Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delay in receiving test results</td>
<td>Increases patient's length of stay; Patient's condition worsens; Patient experiences pain and/or discomfort</td>
<td>Increase/improve staffing of testing centers; Obtain more equipment</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(15) Patient is admitted to an inpatient ward, the Emergency Ward, or the ICU in Victoria</td>
<td>Increases patient's length of stay; Patient's condition worsens; Patient experiences pain and/or discomfort; Patient occupies bed</td>
<td>Increase capacity of hospital; Improve operational efficiency; Create a bed manager position</td>
<td></td>
</tr>
<tr>
<td>Patient is boarded in current department</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patient is admitted to a different, sub-optimal department</td>
<td>Patient does not receive the highest quality care available; Doctor and nursing staff are burdened with a more intensive patient which reduces the department's service efficiency and quality</td>
<td>Increase capacity of hospital; Improve operational efficiency; Create a bed manager position</td>
<td></td>
</tr>
<tr>
<td>(16) Bed and equipment are prepared in the appropriate ward</td>
<td>Bed is not turned over</td>
<td>Delay in servicing patient; Patient condition may worsen; Increases patient length of stay;</td>
<td>1</td>
</tr>
<tr>
<td>--------------------------------------------------------</td>
<td>-----------------------</td>
<td>---------------------------------------------------------------------------------</td>
<td>---</td>
</tr>
<tr>
<td>Required equipment unavailable</td>
<td>Patient transferred to another facility; Patient is boarded in another department</td>
<td>3</td>
<td>Shortage of equipment in hospital; Equipment misplaced</td>
</tr>
<tr>
<td>(17) Staff transports patient and medical records to appropriate ward</td>
<td>Delay in transferring patient</td>
<td>Delay in treating patient; Patient condition worsens; Patient length of stay increases; Patient occupies current bed longer than necessary</td>
<td>2</td>
</tr>
<tr>
<td>Patient records misplaced during transfer</td>
<td>Delay in patient care until file is found; Inappropriate diagnosis or treatment may be serviced</td>
<td>2</td>
<td>Lack of EMR; lack of organization; human error</td>
</tr>
<tr>
<td>(18)</td>
<td>Patient is discharged to a step-up or step-down facility</td>
<td>Inappropriate decision to transfer patient</td>
<td>Patient's length of treatment increases, Patient condition worsens</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

| (19) | Contact is made with step-up or step-down facility | No bed availability at step-up or step-down facility | Patient occupies bed after discharge | 2 | Overcrowding of other medical facilities | 3 | 6 | N | N | N | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

| (20) | Patient is discharged to return home | Inappropriate decision to discharge patient | Patient condition continues to exist and/or worsen; Patient will be readmitted to hospital | 4 | Inexperience d staff | 4 | 16 | Y | N | N | Y |

Create checks with senior doctoral staff

Patient does not understand doctor discharge instructions

Patient condition will relapse or complications may occur; Patient will be readmitted to hospital

Doctor does not properly or fully communicate discharge instructions; Patient's inability to learn tasks

Create a checklist for patient to complete at home by doctor's instructions; Create a final check with doctor upon discharge to go over home instructions
### Social Worker

<table>
<thead>
<tr>
<th>Event</th>
<th>Impact</th>
<th>Frequency</th>
<th>Risk Factors</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delay in obtaining social worker</td>
<td>Increases patient length of stay; Patient occupies bed longer than necessary</td>
<td>2</td>
<td>Insufficient social workers; Social workers overburdened</td>
<td>Y N Y Y</td>
</tr>
<tr>
<td>Social worker not contacted</td>
<td>Delay in patient discharge; Bed occupied longer than necessary</td>
<td>2</td>
<td>Miscommunication of staff; Intranet connectivity slow or down</td>
<td>Y N Y N</td>
</tr>
</tbody>
</table>

### Pharmacy

<table>
<thead>
<tr>
<th>Event</th>
<th>Impact</th>
<th>Frequency</th>
<th>Risk Factors</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delay in filling prescriptions</td>
<td>Increases patient length of stay; Patient occupies bed longer than necessary</td>
<td>2</td>
<td>Insufficient pharmacy staffing; Pharmacy overburdened with high demand</td>
<td>Y N Y Y</td>
</tr>
<tr>
<td>Case</td>
<td>Description</td>
<td>Impact on Patient</td>
<td>Recommendations</td>
<td></td>
</tr>
<tr>
<td>------</td>
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</tr>
<tr>
<td>(23)</td>
<td>Patient transport is arranged (private or ambulance)</td>
<td>Ambulance unavailable for transport</td>
<td>Increases patient’s length of stay; Patient occupies bed for longer than necessary</td>
<td>Improve patient discharge process; Ensure patient is discharged as quickly as possible</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>Ambulance is busy servicing emergent patients</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>6 N N N N</td>
<td></td>
</tr>
<tr>
<td>(24)</td>
<td>Patient exits hospital</td>
<td>Family and/or friends are not notified of discharge</td>
<td>Increases patient’s length of stay; Patient occupies bed for longer than necessary</td>
<td>Improve staff communication; Notify family/friends of discharge</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>Miscommunication of staff; Patient does not provide contact information of family/friends</td>
<td></td>
</tr>
<tr>
<td></td>
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<td>4</td>
<td>8 N N N Y</td>
<td>Improve staff communication; Ensure patient fills out contact information at hospital check-in</td>
</tr>
<tr>
<td></td>
<td>Patient does not have someone to provide transport from hospital</td>
<td>Increases patient’s length of stay; Patient occupies bed for longer than necessary</td>
<td>Family/friends are working or busy; Family/friends do not have a means of transportation</td>
<td>Improve patient discharge process; Ensure patient is discharged as quickly as possible</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>Family/friends are working or busy; Family/friends do not have a means of transportation</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>3 N N N N</td>
<td></td>
</tr>
<tr>
<td>(25)</td>
<td>Patient gets lost exiting hospital</td>
<td>Congestion in hallway from wandering discharged patients</td>
<td>Lack of directional signs; Lack of hospital staff direction</td>
<td>Improve patient navigation; Ensure hospital staff are available to assist patients</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>Lack of directional signs; Lack of hospital staff direction</td>
<td></td>
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<td></td>
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<td>1</td>
<td>1 N N N N</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Delay in patient exit</td>
<td>Increases patient length of stay</td>
<td>No one available to help patient to transportation vehicle</td>
<td>Improve patient navigation; Ensure hospital staff are available to assist patients</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>No one available to help patient to transportation vehicle</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>2 N N N N</td>
<td></td>
</tr>
</tbody>
</table>
BIBLIOGRAPHY


Academic Vita
Kelly P. Gagnon

EDUCATION
Bachelor of Science in Industrial Engineering
The Pennsylvania State University, University Park, PA
Graduation: May 2016

Schreyer Honors College, Honors Thesis in Health Systems Engineering
The University of Cape Town, South Africa
Jan 2015 – June 2015
Study Abroad, Course work in business analytics, engineering, and South African history/culture

WORK EXPERIENCE
Product Sales Specialist Intern, IBM Federal Cloud Software Group
June 2015 – Aug 2015
- Coordinated customer outreach, logistics, and curriculum for three IBM Bluemix Days
- Identified 30 Bluemix Hackathon opportunities and planned outreach strategy for key accounts
- Created a Bluemix web application for Bluemix Days external registration site

Sales and Marketing Brand Ambassador, Leblon Natural Cane Cachaça
Aug 2014 – Dec 2014
- Promoted the product brand to clients by initiating meetings and planning promotional events
- Educated managers and servers on brand initiatives, preparation, and presentation techniques
- Designed and created marketing tools (i.e. table tents, signs, giveaways)

Process Engineering Consultant Intern, Synergetics Consulting
May 2014 – August 2014
- Developed a “How to Operate” manual by functional area in the School Specialty distribution center for supervisors (receiving, staging, stocking, picking, packing, shipping, inventory control)
- Implemented 25 time studies to develop standards/efficiency metrics for daily operating report
- Worked with supervisors/leads to trouble-shoot problems and track lost time

RESEARCH
Healthcare Systems Engineering Thesis, Schreyer Honors College
Mar 2015 – Apr 2015
- Performed observations and collected data at Victoria Hospital (South Africa)
- Researched South African healthcare and current predictive modeling and management platforms
- Designed a functional dashboard to forecast inpatient throughput and resources for Victoria Hospital

Undergraduate Research Assistant, BRITE Lab
Sept 2013 – Dec 2014
- Developed creativity metrics and rated design ideas to track the early cognitive selection process
- Evaluated errors in medical resident aortic catheter insertion to create a new ultrasound haptic model
- Produced informational short films for lab (viewed at www.engr.psu.edu/britelab)

LEADERSHIP
International Engineering Envoy, Penn State College of Engineering
Aug 2015 – Present
- Promoted international opportunities by giving presentations in classrooms and at campus events
- Held office hours for engineering students to plan and prepare for their international experiences

Policy and Standards Board, Pi Beta Phi Fraternity for Women
Aug 2014 – Jan 2015
- Upheld the values of the organization by mentoring 90 new members
- Determined disciplinary action for broken policies or behavioral issues

Academic Facilitator, Penn State Women in Engineering Program
Aug 2014 – Dec 2014
- Organized and led weekly study groups for Linear Algebra and Differential Equations courses
- Mentored 25 students by introducing study skills, resumes workshops, and research opportunities

HONORS
Schreyer Academic Scholarship, Marcus Scholarship, Beabout Scholarship