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Impact of a Localized Lean Six Sigma Implementation on Overall Patient Safety and Process Efficiency

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IMPACT OF A LOCALIZED LEAN SIX SIGMA IMPLEMENTATION
ON OVERALL PATIENT SAFETY AND PROCESS EFFICIENCY

by

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ABSTRACT

IMPACT OF A LOCALIZED LEAN SIX SIGMA IMPLEMENTATION ON OVERALL PATIENT SAFETY AND PROCESS EFFICIENCY

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Old Dominion University, 2017
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Continuous quality improvement tools have been widely used in the Healthcare Industry to increase efficiency and patient safety as well as to reduce cost. This research explores the impact of a Lean Six Sigma (LSS) process improvement initiative on the overall process efficiency and patient safety in the Labor and Delivery (L+D) units of a large hospital provider. This study focuses on the application of a modeling and simulation methodology to investigate the influence of a localized process improvement intervention on the overall L+D unit output by considering patient flow, system capacity, and unit performance. The simulation models capacity profiles and patient flow through the system to determine patient throughput and waiting times. Baseline data was obtained from information systems logs from two Sentara Healthcare. Finally, the simulation analysis provides evidence to support decision making regarding process improvement implementation across the evaluated scenarios; the results evidence a significant time reduction, not only in the registration process but also in the "Time to Arrive to the Physician."

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NOMENCLATURE

LSS	Lean Six Sigma
L+D	Labor and Delivery Process
OPR	Standard Registration System Function
OPRR	Quick Registration System Function
EMTALA	Emergency Medical Treatment and Active Labor Act
HIPAA	Health Insurance Portability and Accountability Act

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CHAPTER 1

INTRODUCTION

The U.S. healthcare system constitutes a complex and highly developed configuration of healthcare services and products. The service delivery is divided into three sectors: public, non-profit, and private. The private healthcare system has maintained a continuing growth trend over the years; however, this growth has not been centered on efficient delivery, patient safety, and organizational management. On the contrary, increased costs have historically been the principal characteristic of the system. According to the World Bank Statistics (2015), private practitioners have traditionally dominated the market by 47.13%. The continued growth in overall healthcare costs has been categorized as a national crisis. The healthcare crisis is considered to be a subject of national concern, since it has a socio-economic impact on employers, employee, financial systems, and the healthcare system itself (Parmenter, 2015).

Continuous quality improvement tools have caught the interest of the Healthcare Industry as a solution to improve process efficiency, patient safety, and healthcare expenditure reduction. In particular, Lean Six Sigma (LSS), first recognized by its business success in the manufacturing industry, has been also applied to healthcare systems. The implementation of LSS has typically targeted patient safety and process optimization by minimizing waste and errors through process reengineering. Early success in LSS use among distinct healthcare processes has been documented in many research studies, which provide evidence of positive outcomes in a variety of contexts, including:

- Reducing wrong surgery risks (M. R. Chassin & Loeb, 2013).

- LSS application for error reduction in the registration process (Riebling et al., 2004).
- Error reduction on medication orders (Esimai, 2006).
- Electronic Health Record optimization (Arlotto, 2014).
- Computerized Provider Order Entry System optimization (Azis & Osada, 2013).
- Billing system optimization (Schoonhoven, Lubbers, & Does, 2013).
- Registration system optimization (Yu & Yang, 2008).

Some researchers have proposed the use of discrete event simulation for analyzing health services processes. Yu and Yang (2008) utilized arena simulation to evaluate patients' registration waiting times in the analyze phase of process reengineering. Particularly, the study that is the subject of this paper has proposed the utilization of arena simulation to analyze and understand the impact of a LSS improvement initiative on the overall Labor and Delivery system.

This study explores the impact of a LSS implementation on the registration process of the Labor and Delivery (L+D) Unit within a large healthcare provider in the Mid-Atlantic region. The LSS implementation was aimed at both improving patient flow and reducing costs, while maintaining compliance with EMTALA (Emergency Medical Treatment and Active Labor Act) and HIPAA (Health Insurance Portability and Accountability Act) regulations.

1.1. Research Problem Statement and Research Questions

This study investigates the effects of an LSS implementation on the registration process of the L+D unit at a large healthcare provider in the Mid-Atlantic region. The research focuses on utilizing discrete event simulation methodology to analyze and understand the impact of a Lean Six Sigma (LSS) process improvement initiative in the overall system.

The following research questions are being investigated:

- What is the impact of the LSS implementation on overall process efficiency?
- What are the impact of changes in the registration processing times and the configuration of resources on the system capacity profile and process outcomes?

1.2. Relevance and Expected Outcomes

The relevance of this study is three-fold. First, it provides a model to analyze the impact of an LSS implementation from the perspective of process efficiency and cost reduction. Second, it utilizes discrete event simulation to support decision making in a variety of scenarios with different levels of resources. Third, it provides a model to empirically evaluate the impact of the improvement in a variety of scenarios.

The results of the analysis are expected to provide information for management in support of decision-making with regard to process improvement implementation. The simulation of multiple scenarios facilitates the evaluation of the impact of an intervention on outcomes in a variety of contexts.

CHAPTER 2

BACKGROUND OF THE STUDY

2.1 Literature Review

A comprehensive literature review was conducted to analyze prior studies on the implementation of Lean Six Sigma methodology in healthcare organizations. The following keywords were used to identify relevant sources through the EBSCO Discovery Service: IT, healthcare system, Lean Six Sigma, healthcare, and information technologies. A search through the Knowledge Center of the American Society of Quality helped identify additional case studies evaluating the impact of LSS implementation on process improvement. The search led to 587 papers, which were evaluated according to their relation to the proposed research question. After review, the number was reduced to 22 final papers that were included in this literature review.

2.1.1 U.S. Healthcare System

According to the World Health Organization (2016), a healthcare system is the configuration of health services that are delivered to users at the time and place where they are needed. The configuration of these components can vary widely from country to country. The United States has three kinds of organizational systems that allow these four components to configure and produce health services for people: governmental health agencies with healthcare functions, the private-nonprofit healthcare sector, and the private-for profit/commercial sector (Jonas, Goldsteen, & Goldsteen, 2013).

The commercial sector has traditionally dominated the U.S. Healthcare System, with its primary base on producing profit for the providers (the private practitioners) (Jonas et al., 2013). According to the World Health Organization Statistics (2014), government expenditure on health comprised 48.29% of total health expenditure, while private expenditure represented 51.7%.

Moreover, the sum of the private funds mobilized for healthcare by private entities is distributed as follows:

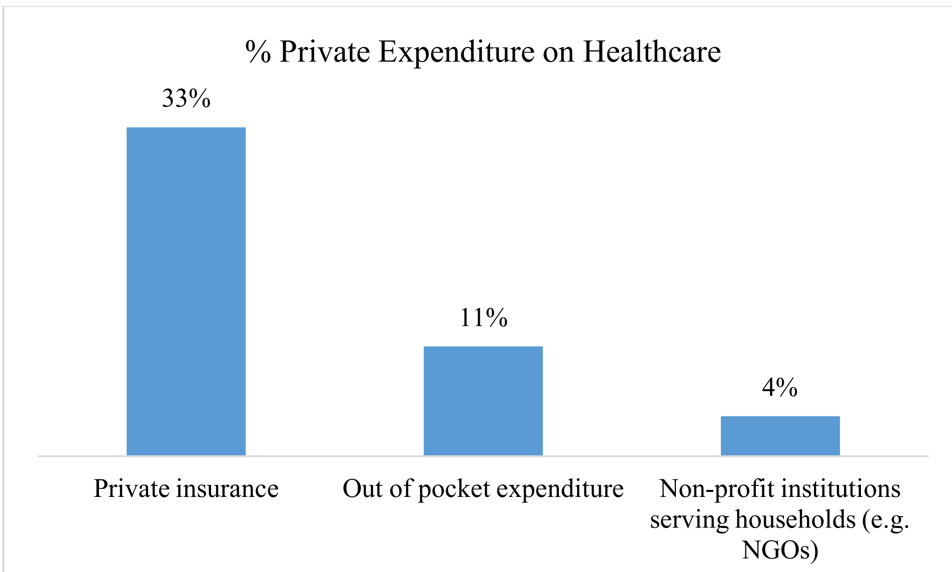

Figure 1: United States Private Expenditure Percentage (Global Health Expenditure, 2017)

The World Health Organization has proposed a measurement framework to evaluate the performance of the healthcare systems around four basic objectives: (1) Health Improvement/Outcomes, (2) Responsiveness and Access, (3) Financial Contribution, and (4) Health Expenditures (Conklin, 2002; Shi & Singh, 2010).

According to the World Health Organization (2015), health expenditures include the costs of health services delivery, preventive as well as curative treatments, family planning, nutrition, and emergency aid. However, there are no provisions made for patient safety.

The US costs of healthcare are estimated as the percentage of healthcare expenditures by the Gross Domestic Product (GDP) (Parmenter, 2015). From a chronological viewpoint, there has been a growing trend in the cost of healthcare since 2000. This increasing rate of healthcare expenditures is considered to be a subject of national concern. The continued increase in costs has an impact on employers, on employee health benefits, on financial systems, and on the healthcare system overall (Parmenter, 2015). Figure 2 represents the growth trend of the Total Health Expenditure percentage of the United States of its Gross Domestic Product from 1995 to 2014.

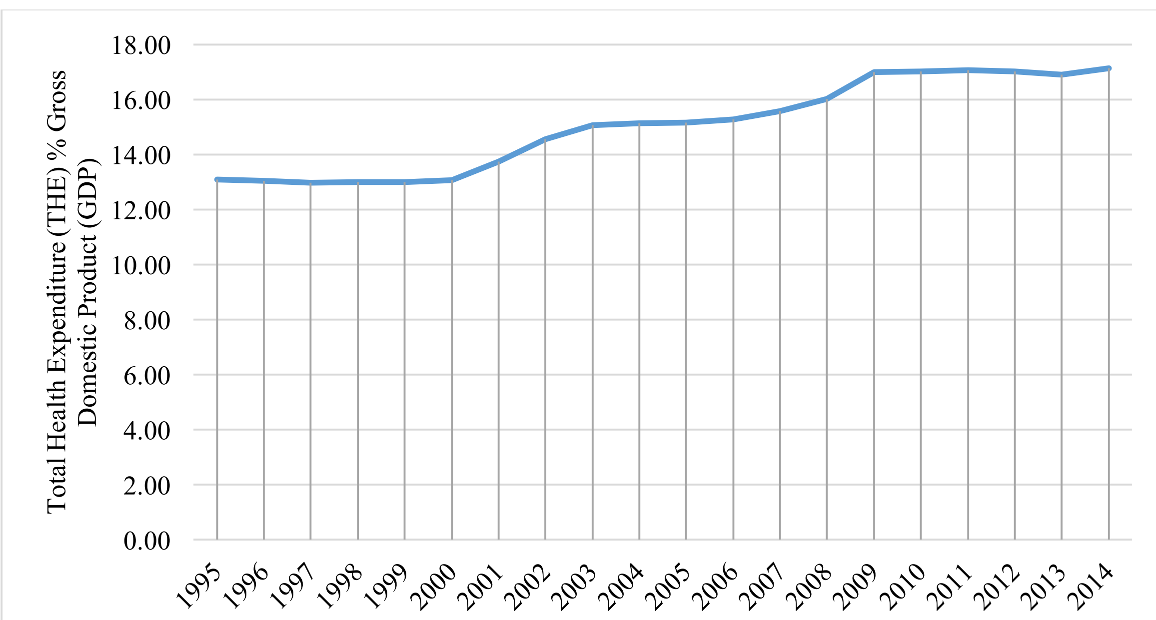

Figure 2: Total Health Expenditure (THE) % of U.S. GDP (Global Health Expenditure, 2017)

Healthcare organizations are aware of the need to create value in healthcare delivery and to reduce cost by eliminating waste in processes. One successful approach to address this problem is the use of LSS methodology, a quality management approach that was first developed in the manufacturing industry because of the combination of two continuous improvement philosophies: waste reduction, or Lean Manufacturing, and error-free process improvement, or Six Sigma (DeBarba et al., 2011).

Lean manufacturing is considered to be a model that drives an organization to clearly identify the points of improvement by eliminating waste. This dynamic and systematic process improvement was originated in response to Japan's crisis after World War II, when the Japanese market was destroyed and the manufacturing processes' productivity was at a low. In response to this crisis, the Japanese industry went through process reengineering by identifying its competitiveness priorities and banishing waste (Drohomeretski, Gouvea da Costa, Pinheiro de Lima, & Garbuio, 2014). Japan eliminated waste from its processes by reducing non-value-added activities, human effort, stock, delivery time, and space. This strategy has been linked to improvements in productivity, product quality, and cost reduction (Drohomeretski et al., 2014).

On the other hand, Six Sigma was first implemented by an American company, Motorola, with the goal of identifying and eliminating the causes of errors in the process, in so doing prioritizing activities that were relevant to clients. The Motorola's Six Sigma strategy success is based on: op management involvement, process infrastructure support, team training, and statistical tools implementation, to standardize processes. In 1988, Motorola's Organization Model (Sig Sigma) was recognized with the Malcolm Baldrige National Quality Award (Drohomeretski et al., 2014).

The integration of Lean Manufacturing and Six Sigma as a combined strategy originated a new business strategy known as Lean Six Sigma (LSS). This approach is aimed at increasing process performance and customer satisfaction, while delivering a profit to the organization. The success of this combined methodology has captured the attention of the healthcare industry (DeBarba et al., 2011). LSS has been suggested as a promising approach to deliver improved and value-based healthcare aligned to the overall goals of healthcare organizations. Prior research in healthcare has reported the impact of LSS on the following quality factors:

- Shortening the length of stay of the patient (Pellicone & Martocci, 2006)
- Reducing medical errors (Buck, 2001; R. Chassin, 2008)
- Reducing registration errors (Dyas et al., 2014; Riebling, Condon, & Gopen, 2004)
- Reducing billing errors (Schoonhoven et al., 2013)
- Improving the efficiency in the medication discharge process (Pocha, 2010)

Among the critical quality factors mentioned above, error reduction is a major concern in the healthcare industry, since errors in healthcare delivery can lead to financial loses and even to patient deaths (e.g., medication errors, wrong doctor’s orders, operating on the wrong organ). Lean strategies have been a reported as a common approach to improve healthcare delivery quality through error reduction (Pocha, 2010).

2.1.2 Lean Sig Sigma Implementation in U.S. Healthcare For Error Reduction

The literature presents documented evidence of the impact of LSS implementation on error reduction for US healthcare providers. The success of LSS initiatives has been documented in a variety of healthcare processes.

Haynes et al. considered the impact of an LSS implementation on error reduction in surgery. The researchers demonstrated an overall reduction in complication rates from 11.0% at baseline to 7.0%, and a reduction in death rates from 1.5% to 0.8%, after the introduction of a surgical safety checklist in eight hospitals in eight cities (M. R. Chassin & Loeb, 2013). Similarly, Riebling et al. (2004) reported on an LSS implementation that contributed to a reduction of human error in their accessioning process (registration of specimen information in the information system). The benefit of the proposed improvements resulted in a 43% capacity upturn and a $339,000 financial improvement/year; the final DPMO (Defects Per Million Opportunities) were calculated for accessioning errors of 1387 with 4.5 six sigma level and a staff proficiency score of 99%.

2.1.3 The Role of it in Healthcare

The medical industry is continuously challenged with increasing regulatory policies, high competition, and operation and administrative costs (Stahl, Schultz, & Pexton, 2003). Technological advances in information technology are being considered as a potential source for improving processes, clinical quality, and patient safety while reducing costs (Stahl et al., 2003). The studies cited above have shown that data sharing has a positive impact on error reduction. Interventions targeting IT systems present an opportunity to improve communication, data sharing, patient safety, and error reduction through computerized physician ordering systems, barcoding, timeline monitoring systems, patient or specimen tracking, patient identification, and EMR databases (Crema & Verbano, 2013).

The America Society of Quality has gathered improvement reports from healthcare organizations that have invested in ICT infrastructure to optimize their processes. Some of the documented improvements will be presented next.

1. Impact of an LSS application on error reduction for medications orders

The management team of a mid-size hospital (anonymous) approved an LSS project for error reduction in medication orders. After utilizing a DMAIC approach, they concluded that the 80% of errors were attributed to orders not received, frequency, duplicate order entry, and dose. _The quality improvement department implemented a Computerized Physician Order Management (CPOM) to improve process efficiency at ordering entry (Esimai, 2006). After implementing the solution, they saw a 55% reduction in errors between February and June of the same year (Esimai, 2006). The benefits of this LSS implementation on labor cost reduction were estimated at $550,000. Furthermore, the improvement in the communication system, in addition to training, helped improve the relationship between nurses and pharmacists (Esimai, 2006).

2. Impact of Electronic Health Record Implementation

According to Arlotto (2014), the healthcare providers have implemented Electronic Health Records (EHRs) as a strategy to gain the greatest value from its systems. Aleem et al. (2015) documented a Lean Six Sigma implementation in the Emergency Room units of two adult primary care clinics of a rural academic institution in the U.S. The purpose of the study was to improve the depression screening process management by utilizing an LSS-DMAIC approach. The process redesign showed positive results, with a screening rate improvement from 17% to 76%.

3. Computerized Provider Order Entry System (CPOE)

Another example of how ICT and LSS can be combined for process improvement is electronic medical order entry through a CPOE system (Radley et al., 2013). A healthcare provider integrated CPOE into its system (Azis & Osada, 2013), which led to a reduction in medical errors. Furthermore, the system contributed to improving the communication between units (Azis & Osada, 2013). One main challenge during the implementation was physician engagement, which was driven by two factors: the adaptability to master a new system methodology, and the increased time to input the medical order information in the systems (Azis & Osada, 2013).

4. Billing System

Healthcare organizations have also recognized the need to improve the billing system to achieve efficiency and cost reduction (Plonien, 2013). In the Netherlands, Beatrix Hospital presented the results of the implementation of LSS methodology to reduce the billing process time. The Lean principles generated data regarding the speed and continuity of the process, and the Six Sigma approach help identify the most time-consuming errors (Schoonhoven et al., 2013). The principal causes of errors in the billing process are described in Table 1. The analysis in this study reported an improvement to the billing system that included the creation of error alerts to reduce the clerks' error validation time, with estimated cost savings of 240,000 euros (M. Schoonhoven et al., 2013).

Table 1: Causes of Errors - Billing System (M. Schoonhoven et al., 2013)

Process Step	Determinant	Effect on A-segment days	Effect on B-segment days
Authorization	Initial registration mistakes	4	3
Validation	Frequency of checks and corrections	21	6
Price Request	Date and frequency of system run	13	13
Price Assignment	Agreements with insurers	0	55

5. Registration Systems

Patient waiting time is another quality variable that impacts the effectiveness and the costs of a process. An emergency department in a hospital utilized a lean approach when studying the waiting time of discharged patients with a registration delay. They determined that 25% of discharged patients were delayed by 25 minutes (Dyas et al., 2014). Through their LSS intervention, their registration time was significantly reduced. Moreover, a cost model was developed to determine the cost-benefit relation associated to Lean improvements (Dyas et al., 2014). After the improvement implementation, the estimated savings were equivalent to seeing 126 additional patients per month (37 admitted, 89 discharged) with potential savings of $630,000 per year (Dyas et al., 2014).

2.1.4 Discrete Simulation in Healthcare LSS Implementation

The cases described above highlight the importance of variables such as patient flow and waiting times for studying quality care delivery. Discrete Simulation has previously been used as a managerial tool for decision-making support that can be used to study these variables. Modeling-and-simulation is considered to be a powerful tool to examine healthcare system scenarios and to help in reducing costs, providing a better understanding of the behavior of the system. Discrete

Event Simulation (DES) has been used to replicate the behavior of a discrete system by means of an analogous source system's scenario to obtain quantitative data. DES high-fidelity models can support decision making and quality improvement efforts by analyzing the impact of possible operational changes. DES substitutes the speculation of the outcomes by data-driven and quantitative methodology, which provides instant and less expensive data to support recommendations.

Prior research has shown the benefit of using DES, using Arena Software and the implementation of LSS operation principles for process improvement. Yu and Yang (2008) used arena simulation to evaluate the behavior of the process by simulating registration waiting times to study the impact of service gaps. Similarly, there is a documented study of the implementation of arena modeling for the analysis of the patients' waiting time at the Emergency Unit of a Colombian Hospital (Medina & Arrieta, 2013). The research assessed the applicability of LSS improvement alternatives and the impact of waiting times on the consultation time. The study showed a positive impact in patients' waiting time and consultation time.

CHAPTER 3

METHODOLOGY

3.1 Overview

This study reports on a simulation study used to assess the LSS implementation impact on two labor and delivery (L+D) Units of Sentara Healthcare. These units provide labor and delivery services for low- and high-risk patients. Hence, time management is considered a crucial factor in patient safety and process efficiency.

The LSS localized process improvement was focused on the registration process and was required to be in compliance with federal regulations, such as the EMTALA and HIPAA. The analysis used discrete event simulation to investigate the impact of the localized improvement of the registration process on the overall L+D unit performance and patient safety. The simulation can be utilized to evaluate different scenarios and to support decision-making without a physical implementation using the actual entities and resources that participate in the overall process. The methodology presented in Chapter 3 describes the LSS improvement implemented and the discrete event simulation methodology utilized for its impact assessment.

3.2 Research Protocol

3.2.1 Description of the L+D Process

This section presents a description of the initial and improved characteristics of the process under study. As illustrated in the process flow chart (Figure 3), the process at the L+D unit starts with the initial registration (higher-priority activity), where the registrar inputs and/or updates the patient's data in the system. Once the registrar has finished the patient registration, he/she continues to perform medium-priority activities, such as charting and confirmation of insurance information. At this point, the information is transmitted through an interface engine and is received at the triage nurse station. Later, the triage nurse performs triage evaluation of the patient (a higher-priority activity) before the patient is admitted to short-stay observation. Once the triage nurse becomes idle, he/she continues to perform the medium priority activities such as chart opening and patient education. Lastly, the physician determines a diagnosis and treatment of the patient and the baby (a higher-priority activity) and documents the outcome.

The critical path of the patient consists of the consecutive activities that the patient needs to go through in order to be evaluated by the physician. Activities in the critical path are considered to be high priority activities (Registration, Triage Nurse Evaluation, and Physician Evaluation) that are critical to guaranteeing patient safety. The medium-priority activities are indirectly associated to the higher-priority activities, but are not considered as urgent or critical to the safety of the patients (mother and baby).

In addition to the higher- and medium-priority activities, the Registrar and the Triage Nurse also perform lower priority activities that are part of their job description but are not associated to the L+D process under study, such as inventory, medical assistance, and patient care.

The information technology systems that support the L+D unit are HBOC and Prelude. In the previous version of the registration process, the patient information was entered and updated by the registrar, utilizing the OPR function. The OPR function captured the patient's information through 18 screens.

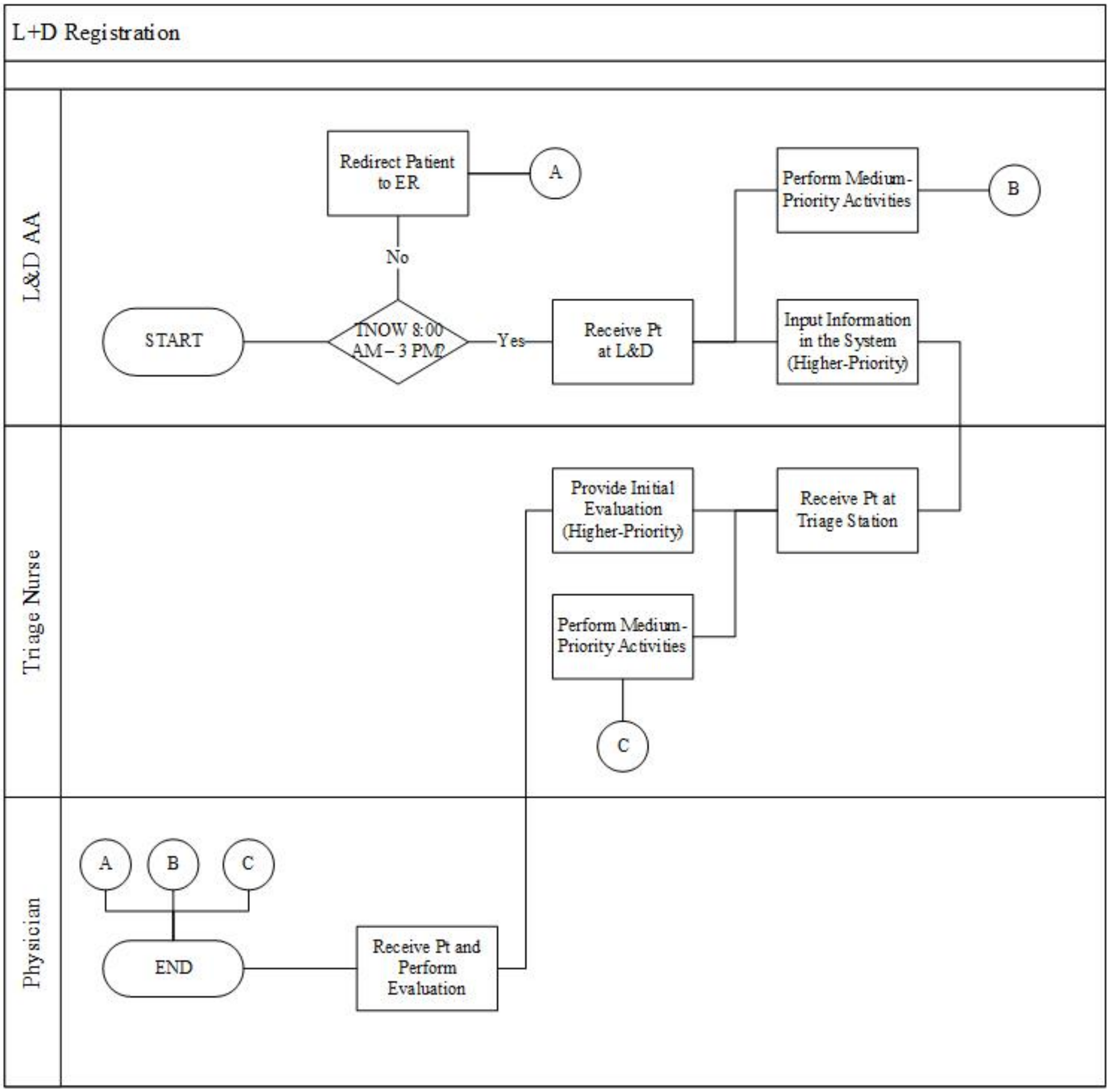

Figure 3: L+D Process - Flow Chart

3.2.2 LSS Improvement Opportunity

The operational effectiveness initiative for quality improvement of the L+D registration process targeted the following objectives:

- Waiting time reduction
- Quick patient flow
- Patient and baby's safety
- Compliance with EMTALA and HIPAA regulations at the entry point of patient registration
- Cost reduction

The hospital team evaluated the registration process by analyzing the information collected to complete the patient registration on every input screen (Appendix A). The OPR function consisted of 18 screens to collect the necessary patient information to complete the registration. However, the team recognized that the registration process could be simplified. The improved process resulted in a reduction in the number of screens that were utilized during the registration process. A new registration system (OPRR) was designed by the IT department to replace the previous system OPR function. The improved process reduced the number of screens from 18 screens to 9 screens (Appendix B) through the new OPRR function. The new process will be referred to as Quick Registration, while the original one will be noted as Standard Registration.

3.3 Simulation Model Design

This section describes the high-fidelity model design utilized to represent the real process. The Discrete Event Simulation (DES) was developed using Arena Rockwell Software. First, the conceptual model developed is presented. Then, the arena model construction, including a description of the input data, entities and resources included, is further explained. The arena model provides the ability to conduct multiple iterative experiments to analyze the impact of the Quick Registration times on the overall system of the L+D unit (patient flow, waiting times, system capacity, and patient safety), with a variety of constraints.

Using the layers of simulation proposed by Balci (2007), the simulation model construction and analysis was developed as follows:

1) Conceptual Model Design
2) Standard and Quick Registration Model Design
3) Simulation scenarios implementation
4) Model validation
5) Models results analysis

3.3.1. Conceptual Model Design

In the conceptualization phase of the study, UML language was used to describe the behavior of the L+D unit. The conceptual model diagram (Figure 4), illustrates the standard visualization of the system, starting from the registration point until the physician's diagnostic:

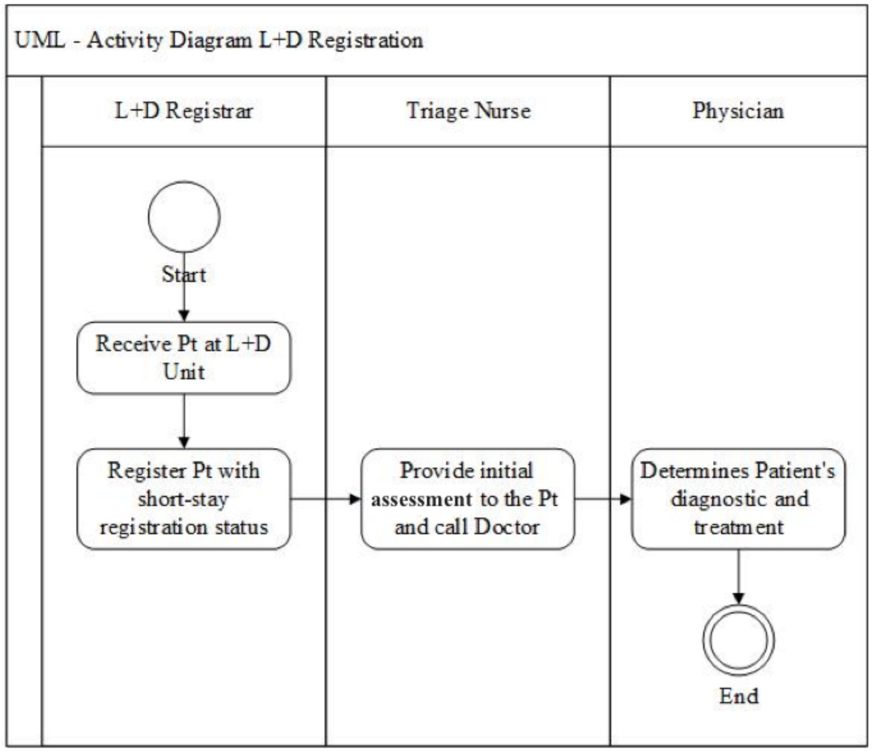

Figure 4: UML - L+D Process

The UML activity diagram illustrates a dynamic view of the higher-priority processes of the L+D unit. The higher-priority processes are the ones whose results are critical to the guarantee of patient safety in the unit; hence, these are categorized as urgent. The workflow described in Figure **4** represents the sequence of activities that the patients go through in order to be evaluated and diagnosed by the L+D unit. The entities moving through the higher-priority activities are the patients. The resources that process the patients are the registrars, triage nurses, and the physicians. The processes performed by the resources are the registration, the triage nurse evaluation, and the physician assessment.

The higher-priority processes are considered to be critical, due to the risk associated to the patients that arrive to the unit. The evaluation of these processes, under different scenarios, is a cornerstone to answer the proposed research questions. The simulation under different conditions will enable the assessment of the impact of the process improvement on the overall system by analyzing processing times, waiting times, and system capacity. To build a high-fidelity model, the simulation will also include the medium and lower-priority processes performed by the registrars and the nurses. The medium priority processes refer to the ones that are indirectly associated with the higher-priority processes, but that do need to be done in urgently manner. And, the lower-priority processes refer to the specific tasks performed by the entity that are not associated with the high-priority processes. These will be further described in section 3.3.2.

3.3.2. Simulation Model Construction

As mentioned above, the simulation software utilized to achieve the LSS localized improvement assessment is Arena Rockwell Software. Arena enables the development of scenarios with different configurations of resources that allow for evaluation of the impact in the waiting times, patient flow, resource utilization, and patients' throughput. The following section presents a detailed description of the components and the workflow of the model. The content will be structured according to the model components, which include entities, resources and processes.

Entities

Patients are the main entities processed through the system. The patients arrive to the unit and continue their flow through the registration, the triage nurse evaluation, and the physician evaluation modules. There are also parallel activity entities, which represent the medium and lower-priority activities performed by registrars and triage nurses that are still part of their daily job but are not directly associated with the high priority task.

Resources

There are three main types of resources in the model: registrars, triage nurses, and physicians. Registrars represent resources that perform the patient registration activities as well as the parallel activities associated the registration process and patient processing. Triage nurses perform the triage evaluation as well as the parallel activities associated with triage and patient processing. Physicians are the resources who perform the medical assessment of the patient.

Processes

Registration represents the process by which the registrar welcomes patients coming in to the L+D unit and inputs all of the relevant data in the system. There are also a set of registration medium-priority processes which represent the activities performed by the registrar that are indirectly associated to the registration of patients, such as filing paperwork, checking insurance, etc. A third category of registration activities are the registration lower-priority processes, which represent the activities performed by the registrars that are not associated with the registration of patients but that are also part of their job description. Table 2 outlines the major tasks included in the medium- and lower-priority processes.

Table 2: Registration Medium- and Lower-Priority Processes

Process	Priority	Tasks
Registration medium-priority processes	Medium	1. Coordination of Referrals for mother and baby 2. Chart/Record Maintenance: Initiation, maintenance, and updating of patient charts, inserting appropriate forms, insurance, ancillary department reports, consults, etc.
Registration lower-priority processes	Low	1. Medical Assistant duties as needed (PRN) 2. Supplies and equipment stocking (inventory)

The Triage nurse evaluation represents the process in which the triage nurses perform the first evaluation of the patient, or the "triage evaluation." The second set of activities performed by the triage nurse are the medium-priority processes which represent the processes performed by the triage nurse and that are indirectly associated to the patient triage evaluation activities, such as patient education. The third set of activities included are the lower-priority processes which are performed by the triage nurse and that are not part of the patient triage evaluation activities. Table 3 enumerates the activities included as medium- and low-priority parallel activities.

Table 3: Triage Evaluation Parallel Processes

Process	Priority	Tasks
Triage nurse medium-priority processes	Medium	1. Chart opening and Initial documentation 2. Patient Education
Triage nurse lower-priority processes	Low	1. Patient care activities

Finally, the Physician Evaluation process represents the process in which the physician diagnosis for patient and baby and treatments: baby demise, natural delivery, or complications.

3.3.3. Arena Simulation Model

Arena Software was used to model the L+D system because of its flexibility and the application's level of detail. Figure 5 illustrates the simulation model for the Labor and Delivery unit. The model integrates all of the resources and processes described in the previous section.

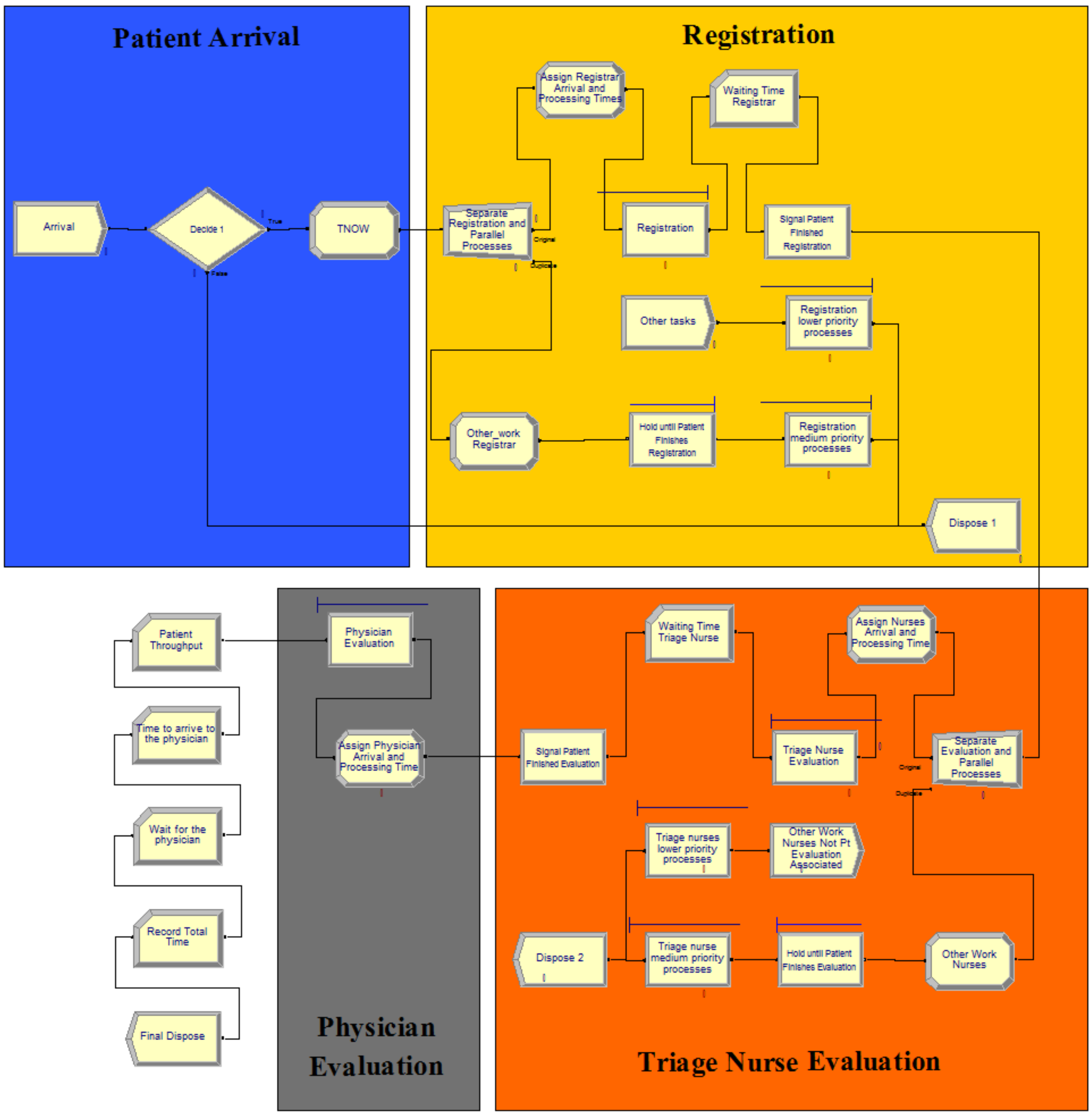

Figure 5: Arena Simulation Model

The logical flow of the model starts from the arrival of a single patient to the unit. Next, this entity continues to the decision point, TNOW. TNOW feeds the patient arrival time to the system. If the patient arrived within the unit's main operating hours, then the patient continues through the unit. Otherwise, the entity goes to Dispose 1. Then, the patient continues to the registration process. The separate module duplicates the entities for the parallel process, a registration medium-priority process. Here, the module "Hold" holds the entities (the patients) until they have completed registration, and that is indicated by Signal module which then tells Hold to free up the resource (registrar) to perform other tasks indirectly associated to the registration process (medium-priority tasks). After finishing the registration, the patient continues to the triage nurse evaluation. The separate module duplicates the entities for the parallel processes (medium-priority process for the triage nurse). The module Hold waits for the Signal of completed evaluation, and then frees up the resource (Triage Nurse) to perform other work associated to triage evaluation, as medium-priority. Finally, the patient finishes the cycle with the physician evaluation process module. In addition to the process flow explained above, the registration lower-priority processes and the triage nurse's lower-priority process are performed by the registrar and triage nurse, respectively, once they finish the higher- and medium-priority tasks.

3.4 Background and Model Implementation

This section describes the implementation of the simulation model. The subsections include detail about the input analysis, the parameters, and some assumptions. Lastly, the results include output analysis, sensitivity analysis, and optimization results.

This project was conducted in a large healthcare provider in the Mid-Atlantic region. The LSS improvement of the registration process was implemented at two L+D units of the hospital. From a visual analysis of the historic data, it can be inferred that the LSS improvement of the registration process implemented at two units reduced the registration processing time and increased process efficiency. Nonetheless, the impact of the LSS implementation on the overall unit is unknown. The comprehensive analysis of the system behavior and outcomes could help to support decision making without incurring an additional cost for physical implementation. The dynamic view of the L+D unit through the arena simulation model enables impact assessment in a variety of scenarios. The analysis of the results lays down evidence to evaluate the big picture of the impact resulting from the change of the registration process on the overall system. The proposed analysis of system behavior and outcomes will include the following Arena applications: Input Analyzer, Output Analyzer, Process Analyzer, and Opt Quest.

3.5 Data Collection

This section summarizes the data collected for the model construction. The model data was obtained from information systems logs of two Sentara Hospitals. Data collected includes: processing times, patient total throughput, entities, and resources. Processing times reflect how long it takes a given resource to complete the prescribed procedures. Patient total throughput refers to the average number of patients processed daily from 8:00 AM to 3:00 PM. This schedule represents the main operating hours of the unit. Patients who arrive outside of regular operating hours are processed by the Emergency Room unit. The entities in the model comprise the patients and the parallel activities entities. And the resources are the registrars, the triage nurses, and the physicians.

A subject matter expert from Sentara provided information regarding the task effort percentages of the registrar and the triage nurses. The Task Effort refers to the estimated percentages of time that the resources allocate to complete each process. As for the registration processes, 15% is dedicated to registration (higher-priority processes), 45% to medium-priority processes, and 40% to lower-priority processes. Further, regarding triage nurse evaluation processes, 55% is dedicated to triage nurse evaluation (higher-priority processes), 15% to medium-priority processes, and 25% to lower-priority processes. Information regarding the distribution of the arrival rate of patients was obtained from prior research on hospital registration units (Yu & Yang, 2008).

3.5.1 Input Data Analysis

The processing times were analyzed by utilizing the Arena Input Analyzer tool. This includes the times for standard registration, quick registration, triage nurse evaluation, and physician evaluation. Each data set was fitted to a distribution in order to find the appropriate distribution to apply in the model.

Standard registration processing time

Based on the Minimum Square Error value (0.003973), the best distribution for the standard registration processing time was the uniform distribution. The parameters of the distribution describe a minimum value of 4 min and a maximum value of 15 min. Figure **6** illustrates the histogram of the standard registration distribution.

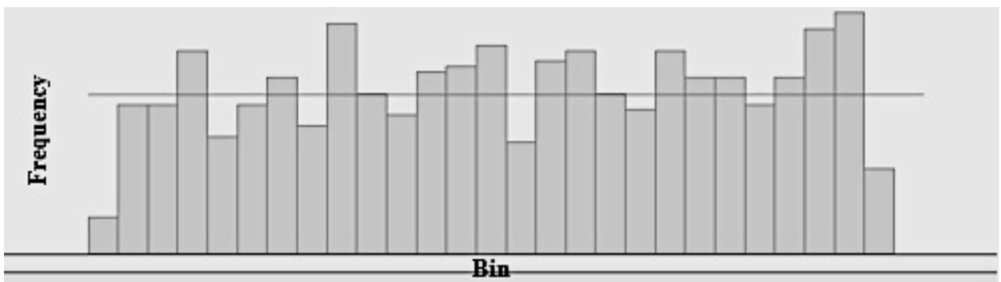

Figure 6: Standard Registration Distribution

The distribution summary of the Standard Registration has been summarized in Table 4.

Table 4: Distribution Summary Standard Registration

Uniform
Distribution: Uniform Expression: UNIF(4, 15) Square Error: 0.003973 Chi Square Test Number of intervals = 28 Degrees of freedom = 27 Test Statistic = 92.9 Corresponding p-value < 0.005

Quick registration processing time

Based on the Minimum Square Error value (0.004998), the best distribution for the quick registration processing time was the triangular distribution. The parameters of the distribution consist of a minimum value of 1 min, a maximum value of 3.7 min, and a mode value of 3 min. Figure 7 illustrates the histogram for the quick registration distribution.

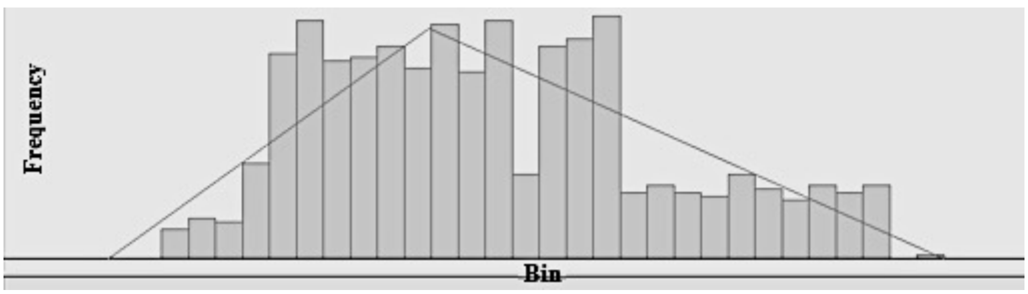

Figure 7: Quick Registration Distribution

The distribution summary of the Standard Registration has been summarized in Table 5.

Table 5: Distribution Summary - Quick Registration

Triangular	
Expression:	TRIA(1, 3.3, 7)
Square Error:	0.004998
Chi Square Test	
Number of intervals	= 28
Degrees of freedom	= 26
Test Statistic	= 138
Corresponding p-value	< 0.005

Triage nurse evaluation processing time

The best distribution for the triage nurse evaluation processing time was the uniform distribution. The parameters of the distribution include a minimum value of 26 and a maximum value of 87. Figure 8 illustrates the histogram of the triage nurse evaluation distribution.

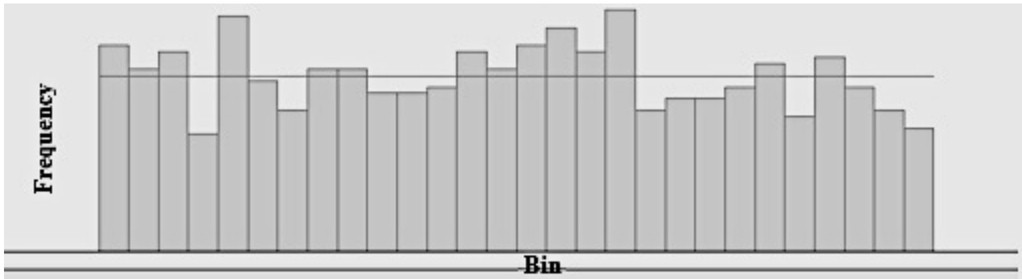

Figure 8: Triage Nurse Evaluation Distribution

The distribution summary of the Standard Registration has been summarized in Table 6.

Table 6: Distribution Summary Triage Nurse Evaluation

Uniform
Expression: UNIF(26, 87) Square Error: 0.001148 Chi Square Test Number of intervals = 28 Degrees of freedom = 27 Test Statistic = 26.8 Corresponding p-value = 0.476

Considering the Chi-Square results, where the corresponding p-value is higher than the significance level (α=0.05), we fail to reject the null hypothesis that uniform distribution is a reasonable fit for the Triage Nurse Evaluation distribution.

Physician evaluation processing time

Based on the minimum square error value (0.004779), the best fit for the physician evaluation processing time was the beta distribution. The expression of the distribution was 8 + 66 * BETA (2.06, 1.4), with a corresponding p-value < 0.005. Figure **9** illustrates the histogram of the physician evaluation distribution.

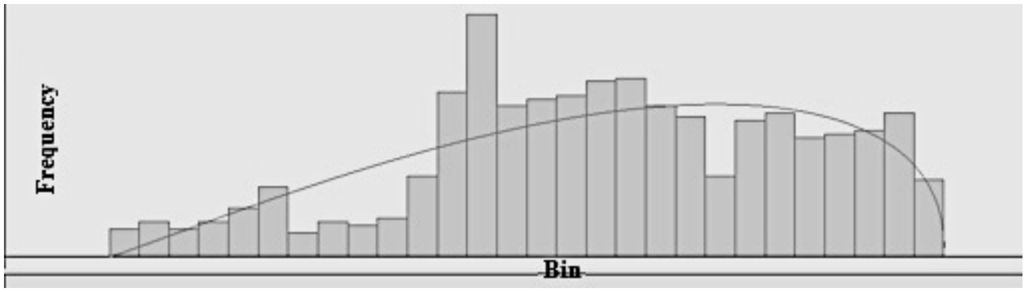

Figure 9: Physician Evaluation Distribution

The distribution summary of the Standard Registration has been summarized in Table 7.

Table 7: Distribution Summary Physician Evaluation

Beta	
Expression:	8 + 66 * BETA(2.06, 1.4)
Square Error:	0.004779
Chi Square Test	
Number of intervals	= 26
Degrees of freedom	= 23
Test Statistic	= 115
Corresponding p-value	< 0.005

Chi Square Test results for the Standard Registration, Quick Registration, and Physician Evaluation were statistically significant at the 95% confidence level indicating that the hypothesized distributions are not an ideal fit to the data. The lack of fit can be partially explained by the small sample of historical data (Kelton, 2002). However, the distributions previously described can be still considered as the most likely distributions to represent the system characteristics. Therefore, for input modeling, the utilized distributions will be uniform, triangular, and beta for the Standard Registration, the Quick Registration, and the Physician Evaluation respectively.

3.5.2 Output Variables

The output variable analysis provides the performance measures information to evaluate and understand the system under study.

- Patient Throughput is the average number of patients that are processed in the unit each day.
- Arrival to the Physician is the average time that it takes to a patient from the arrival point until he or she is evaluated by the physician.
- Total Time in the System is the average time that it takes to the patient from the arrival point until he or she finishes the physician evaluation.
- Utilization rate of resources in the system:
  1. Registrars
  2. Triage nurses
  3. Physicians
- Waiting Times is the average time that elapses between the following stations:
  - Patient's first entrance – Registration
  - Existing registration – Starting triage nurse assessment
  - Existing triage nurse assessment – Starting Physician diagnosis

3.5.3 Model Assumptions

The participating healthcare organization provided comprehensive information regarding the task effort distribution of the resources during a regular workday. The model was developed using the regular hours of operation as 8:00 AM to 3:00 PM; therefore, the total labor time/day was 7 hours. The patient arrival rate (two patients/hour) was estimated based on the average of patient throughput per day. The distribution utilized to model patient arrivals was Poisson, which was found to be ideally fitted in a similar context in past research (Grimaldo et al., 2015). Due to the insufficient historical data points, it was assumed that the best fitted distributions for the

Standard Registration, Quick Registration, and Physician Evaluation are uniform, triangular, and beta respectively.

Within the registration module, patient data input during the registration process was the highest priority activity for the resource, representing 15% of the total labor time/day. Regarding the triage nurse evaluation, the highest priority activity represented the 55%. Lastly, the transportation times between successive stations (registrar, triage, and physician evaluation) were included in the processing time of each module.

CHAPTER 4

DATA ANALYSIS

4.1 Standard and Quick Registration Simulation Model

Regarding the set-up parameters of the simulation, the model was run with a base time unit of minutes. The system was modeled as a terminating simulation, meaning that it has a specific starting and stopping condition. This condition states that if the entity patient arrives outside of the main operating hours (8:00 AM – 3:00 PM), the entity will not be processed in the system. In real life, though, patients arriving outside of the main operating hours are processed through the Emergency Room unit.

The simulation was run with 150 replicates of one day (7 hours/day). Based on the simulation results of the first scenario for standard registration, the total number of replicates (n) was calculated based on pre-set half-width values utilizing the following formula:

$$n = t^2_{n-1,1-\alpha/2} \frac{S^2}{h^2}$$

Where:

n= No. of replications

$t^2_{n-1,1-\alpha/2}$= Critical value from t tables

S^2 =Sample standard deviation

h^2= Pre-specified half-width value

Therefore, by solving the above formula for n, it was found that for a pre-specified half-width value of 5, n would be equivalent to 48; and for a pre-specified half-width value of 3, n would be equivalent to 132. Nonetheless, considering the results from the first run of the model with 150 replicates, where the half-width value for the "Time to Arrive to the Physician" was 0.61, it was found that with this number of replicates, the half-width value (0.61) represented a 0.09% error in the point estimate 65.65 min ($\bar{X}$). Hence, this was considered the most satisfying number of replicates (n=150) to run the model with a higher precision.

The proposed simulation evaluates three different scenarios regarding the configuration of resources:1) Infinite Resources (2) 6 Registrar, 9 Nurses, and 6 Physicians (3) 4 Registrars, 3 Nurses, and 3 Physicians. The first scenario assesses the optimal processing time with unconstrained resources in the system. The second and third scenarios represent actual resource configurations of L+D units from the healthcare organization under study.

4.1.1 Model Validation

The model validation was conducted to demonstrate that the simulation modeled was a high-fidelity representation of the L+D units (Altiok & Melamed, 2010). For this, the animation of the simulation was used to verify the model logic, by assessing the entities' animated flow through the model. In addition, the Subject Matter Expert also conducted a careful examination of the assumptions, model behavior, parameters, output values, and conclusion.

It is noteworthy to mention that validating the simulation based on the quantitative inspection of performance measures such as *Arrival to the Physician* and *Total Time in the System* was not reliable. This was because the historical collected data used for the model did not include Waiting Times, which were simulated in the system.

4.1.2 Scenario Analysis and Comparison

The simulation results were analyzed based on the output variables, including Total Time until Arrival to the Physician, Total Waiting Time, Resource Utilization Rates and Total Patient Throughput. The time that it takes the patient until the physician conducts the evaluation is considered critical for patient safety and for service quality delivery, due to the risks associated to the patients that have not yet Arrived to the Physician.

Scenario 1: Infinite Resources

Results, in the case of unlimited resources, indicate that the time it takes for the patient to arrive to the physician in the system with Standard Registration is 65.63 min, while for Quick Registration it is 60.56 min. Table 8 presents a summary of the simulation results of the Standard and Quick Registration for the first scenario.

Table 8: Scenario 1 Results for Standard and Quick Registration

	Standard Registration				Quick Registration			
	Average	Half Width	Minimum Average	Maximum Average	Average	Half Width	Minimum Average	Maximum Average
Time to Arrive to the Physician (min)	65.63	<0.61	52.96	75.37	60.56	<0.60	52.79	69.85
Utilization Nurses	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Utilization Physician	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Utilization Registrar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Waiting Time Triage Nurse	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Waiting Time	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Registrar								
Waiting Time Physician	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Patient Throughput	25.29	<0.99	8.00	40.00	26.41	<0.81	10.00	39.00

The utilization rates of 0% evidence the fact that having infinite resources will generate no waiting times for any of the modules in the system.

Scenario 2: 6 Registrars, 9 Nurses, and 4 Physicians

Table 9 summarizes the simulation results of the Standard and Quick Registration for the second scenario. The results indicate that the Time to Arrive to the Physician with Standard Registration is 66.51 min, while with Quick Registration it is 60.86 min. The patient throughput in the Standard registration is 26.19, and it is 26.48 in the Quick Registration.

Table 9: Scenario 2 Results for Standard and Quick Registration

	Standard Registration				Quick Registration			
	Average	Half Width	Minimum Average	Maximum Average	Average	Half Width	Minimum Average	Maximum Average
Time to Arrive to the Physician (min)	66.51	<0.58	55.12	78.33	60.86	<0.58	52.21	71.19
Utilization Nurses	0.31	<0.01	0.21	0.43	0.32	<0.01	0.21	0.47
Utilization Physician	0.41	<0.01	0.22	0.65	0.43	<0.01	0.20	0.66
Utilization Registrar	0.69	<0.01	0.59	0.81	0.66	<0.01	0.55	0.78
Waiting Time Triage Nurse	1.29	<0.35	0.00	15.83	1.67	<0.42	0.00	14.25
Waiting Time Registrar	0.41	<0.04	0.00	1.56	0.33	<0.03	0.00	0.88
Waiting Time Physician	0.12	<0.03	0.00	0.88	0.14	<0.04	0.00	2.03
Patient Throughput	26.19	<0.92	11	42	26.48	<0.98	8.00	41.00

The utilization rates show that the registrar (70%) is the resource with the higher utilization in the system. On the other hand, the higher waiting times were found at the triage nurse station (1.29 min/patient).

Scenario 3: 4 Registrars, 3 Nurses, and 3 Physicians.

Table 10 reveals the results of the Standard and Quick Registration for the third scenario. The results indicate that Time to Arrive to the Physician with Standard Registration is 83.71 min, while in the system with Quick Registration it is 78.83 min. The patient throughput in the Standard registration is 25.84, and it is 25.34 in the Quick Registration.

Table 10: Scenario 3 Results for Standard and Quick Registration

	Standard Registration				Quick Registration			
	Average	Half Width	Minimum Average	Maximum Average	Average	Half Width	Minimum Average	Maximum Average
Time to Arrive to the Physician (min)	83.71	<2.34	60.41	134.42	78.83	<2.21	55.43	136.01
Utilization Nurses	0.89	<0.02	0.63	0.99	0.89	<0.02	0.56	0.99
Utilization Physician	0.54	<0.01	0.28	0.78	0.54	<0.02	0.21	0.81
Utilization Registrar	0.98	<0.00	0.87	0.99	0.96	<0.01	0.83	0.99
Waiting Time Triage Nurse	15.93	<2.11	1.83	62.27	16.41	<2.05	0.00	66.70
Waiting Time Registrar	2.01	<0.07	0.74	3.43	1.79	<0.08	0.66	3.11
Waiting Time Physician	1.91	<0.31	0.00	9.93	2.09	<0.38	0.00	12.11
Patient Throughput	25.84	<0.88	8.00	41.00	25.34	<1.05	4.00	42.00

Results from Scenario 3 indicate that the registrars have the highest utilization rate (98%), closely followed by the nurses (89%). The drastic reduction of resource allocation between scenarios 2 and 3, resulted on increased waiting times at the triage nurse (up to 15.93 minutes per patient in the standard registration and 16.41 minutes per patient in the quick registration) when compared to scenario 2. Consequently, the "Time to Arrive to the Physician" measure from Scenario 3 was increased by an average of 17.20 minutes per patient in Standard Registration and 17.97 minutes per patient in Quick Registration, when compared to Scenario 2.

We conducted a simulation experiment using 30 observations to statistically compare the impact of the Quick Registration on the Arrival to the Physician time for all the scenarios. The data was analyzed using an unpaired T-test to determine whether there was a significant difference in the average patient time in the system. Results indicate that the Quick Registration saves patients an average of 5.29 minutes in Scenario 1, 5.63 minutes in Scenario 2, and 4.72 minutes in Scenario 3. These results indicate that the difference between each scenario is too far from zero to be reasonably explained by random noise.

The output analyzer compiled the analysis from the 150 replications data for each scenario. A Two-Sample t-test was used to compare the average time to reach the physician. The Output Analyzer tool performed the means comparison of the "Time to Arrive to the Physician" measure by subtracting A-B (Standard Registration Scenario minus Quick Registration Scenario).

4.1.3 Sensitivity Analysis

Considering the potential risk for patients coming to an L+D unit, the time savings noted above can make a difference in patient safety outcomes and quality of service. This methodology has studied three different configurations of resources. The Arena Process Analyzer was the tool utilized to perform the scenario analysis.

A sensibility analysis was included to get a deeper understanding of the behavior of the time difference associated with the LSS improvement at the registration process. The results of the sensitivity analysis for both resources (Registrars and Nurses) were plotted.

The Sensitivity Analysis Plots for the number of registrars (See Figure 10) and the number of nurses (See Figure 11) illustrate the time improvement in the system as a function of the number of resources. The time improvement is represented by the gap between the two lines. Furthermore, based on the slopes of the linear equations presented in each graph, it can be inferred that the behavior of the "Time to Arrive to the Physician" is the same for the Standard and Quick Registration.

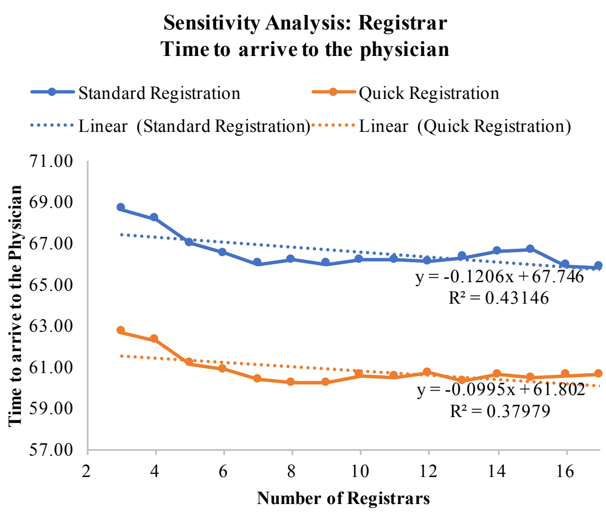

Figure 10: Sensitivity Analysis – Registrars

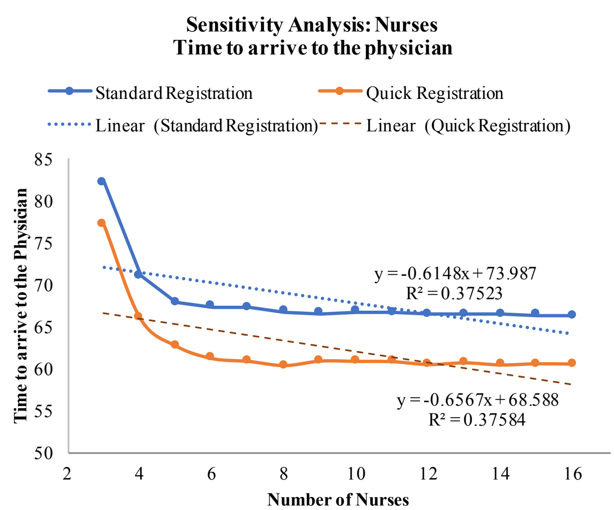

Figure 11: Sensitivity Analysis – Nurses

Moreover, it was found that the impact of the Quick Registration on the Arrival to the Physician Time was consistent and independent from the configuration of resources in the system. This positive effect does not generate any delay in the triage nurse and physician evaluation.

The proposed model can be utilized to support decision-making by facilitating the evaluation of different scenarios without incurring any additional costs or risks to patients. This methodology was developed to meet the features and requirements of the L+D unit. Although this model might be applicable to similar L+D units, it might require modifications with regard to inputs, outputs, and resources.

4.1.4 Optimization Analysis

Based on the analysis of scenarios and the sensitivity analysis results, it could be evidenced that the impact of the Quick Registration Improvement is independent from the configuration of resources. Nonetheless, the results also demonstrated how the configuration of resources could impact in the Utilization Rate of Resources, Waiting Times, and the Time to Arrive to the Physician.

Given the criticality associated with the Time to Arrive to the Physician in terms of patient safety and process efficiency, it is fundamental to determine the best allocation of resources in the system that guarantee the minimum time of the patient in the system before he or she is finally evaluated by the physician.

The OptQuest Arena tool was implemented to explore different alternatives of the configuration of resources in a quest to minimize the “Time to Arrive to the Physician” measurement.

Objective Function = Minimize (Time to Arrive to the Physician)

The evaluated scenarios were subject to the requirements of a Total Daily Cost of Resources not higher than $6,321.00, a Time to Arrive to the Physician not higher than 65 minutes, a Utilization Rate of Resources not higher than 80%, and a Patient Throughput of at least 16 patients/day.

The information utilized in the constraint defined as the “Daily Cost of Resources” was obtained from the salary.com database; the daily salary was computed considering a total of 7 working hours/day for each of the resources. The detail is listed as follows:

Registrars = $105/ day

Triage Nurses = $259/day

Physicians = $840/day

The value of the constraint “Total Daily Cost” ($6,321.00), was based on the daily cost of the configuration of resources presented in Scenario 2 from the Scenarios Analysis discussed in Section 4.1.2 Scenario Analysis and Comparison. Scenario 2 presented the best “Time to Arrive to the Physician” among the evaluated scenarios; the Total Cost for its configuration of resources was $ 6,321.00. Therefore, the simulation with OptQuest was configured to consider all of the feasible solutions with a Total Daily Cost lower the one calculated based on the Scenario 2 configuration.

Based on the OptQuest results, the best "Time to Arrive to the Physician" was equal to 63.91 min, with the following configuration of resources:

Table 11: Best Solution OptQuest

	# of Resources
Registrars	6
Nurses	8
Physician	4

CHAPTER 5

CONCLUSION

The objective of the present study was to explore the impact of a Lean Six Sigma (LSS) operational effectiveness initiative on two L+D units of Sentara Healthcare. The methodology relied on Arena Simulation Modeling to design a high-fidelity model of the real-life L+D unit and to conduct iterative experiments in the system.

The results of the simulation analysis provided evidence to support that the change of the registration process generated a consistent reduction on "Time to Arrive to the Physician" measure. In addition, the unpaired T-test analysis evidenced a significant difference in the average patient time that a patient in the system took to Arrive to the Physician.

Moreover, based on the sensitivity analysis, it can be stated that the improvement was consistent and independent from the configuration of resources; further, it was found that the change in the registration process did not cause any delay in the further stations of the process (i.e., triage nurse or physician evaluation).

Furthermore, the utilization of Arena Suite for the optimization analysis provided valuable information to support decision making in terms of resource allocation. The results of the analysis performed on OptQuest tool provided knowledge regarding the optimal configuration of resources. According to the optimization results, the best “Time to Arrive to the Physician” was 63.91 min, allocating 6 registrars, 8 nurses, and 4 physicians.

Altogether, the points considered above provide evidence to support that the localized change of the registration process in the case study generated an overall positive impact by reducing not only the registration time, but also the Time to Arrive to the Physician, which is considered critical to patient safety.

Results from this study may not be generalized to other settings since the model parameters belong particularly to this case study. Future evaluation of other L+D units utilizing simulation should be customized to the characteristics of the new system under study. To avoid some of the limitations found in this study, future studies should use daily historical data to build the simulation model.

Finally, the implementation of Arena simulation to answer the research question proved to be a flexible and powerful tool to analyze and understand the behavior of the system without incurring any additional costs or risks to patients. However, considering that the evaluation has been particularly developed to evaluate an already implemented improvement in the L+D unit, future research could:

- Model the L+D department including rest periods
- Model the L+D room, including prioritization of High-risk patients
- Study the impact of potential improvement initiatives
- Expand the research methodology to study and analyze other hospital departments
- Develop a methodology to measure the impact of the time savings on patient risk.

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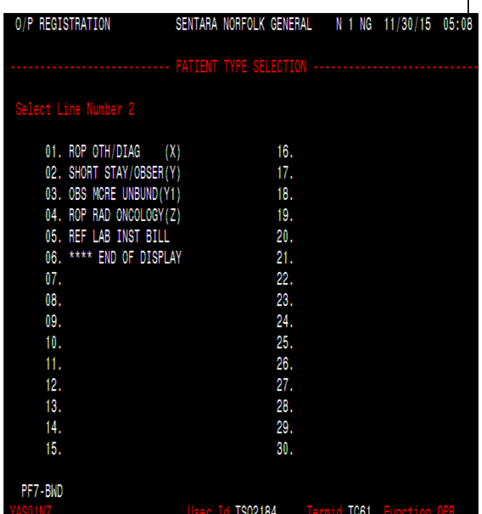
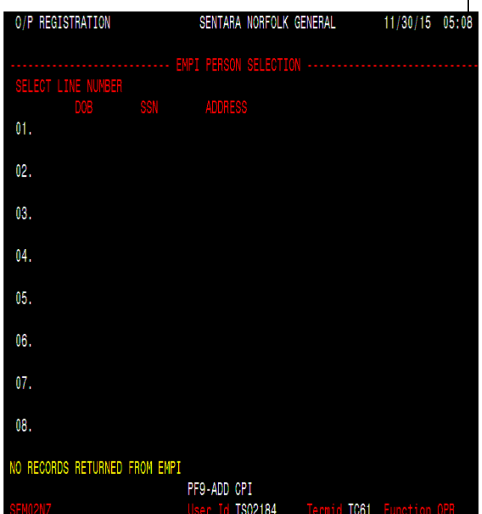
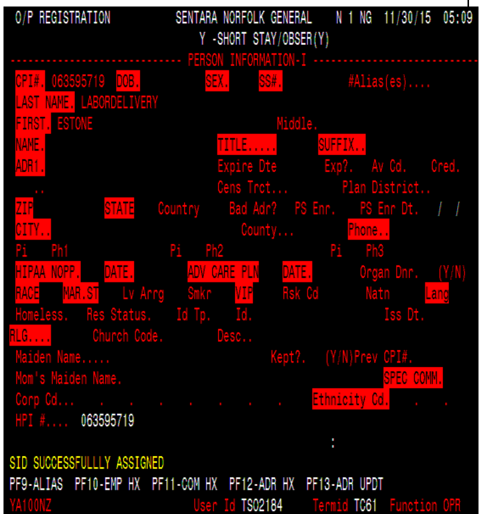
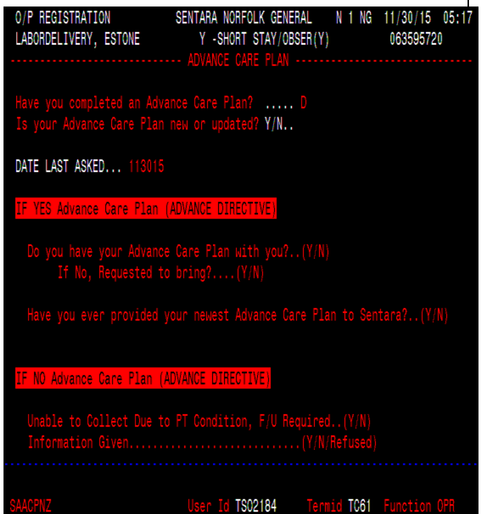
APPENDICES

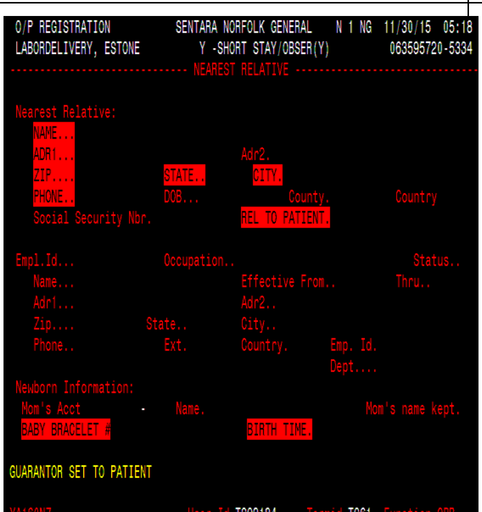
APPENDIX A: OPR FUNCTION DESCRIPTION

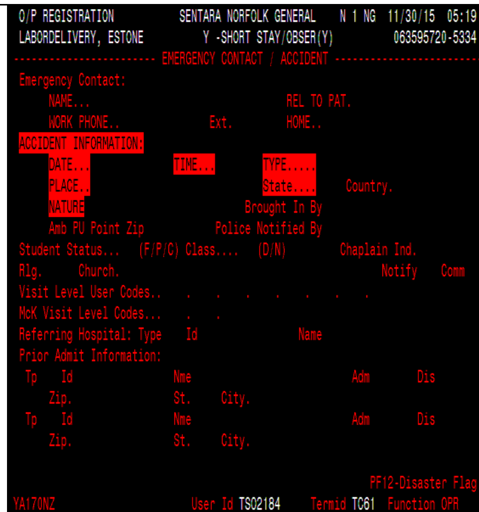
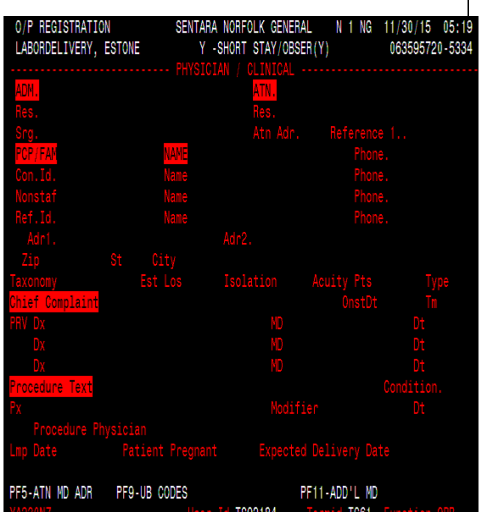
<table>
<tr><th colspan="4">OPR – Initial Methodology</th></tr>
<tr><th>Screen Number</th><th>Image</th><th>Fields</th><th>Standard Time</th></tr>
<tr><td>1</td><td>
</td><td>Patient Type Selection</td><td></td></tr>
<tr><td>2</td><td>
</td><td>Patient type selection</td><td></td></tr>
</table>

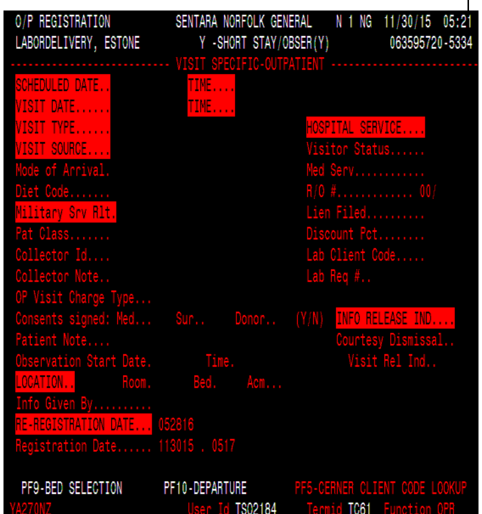
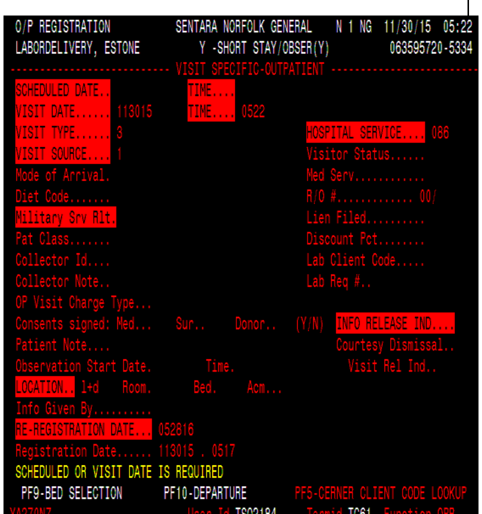
<table>
<tr>
<td>3</td>
<td>
</td>
<td>EMPI search parameters
-SS#, Last name, First name, Middle Name, Title, Suffix, Sex, Race, Birthdate (MM DD CCYY), Mom’s Middle Name, State of residence.
-Medical record number
-CPI Number</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>
</td>
<td>EMPI person selection:
-DOB
-SS#
-Address</td>
<td></td>
</tr>
</table>

<table>
<tr>
<td>5</td>
<td>
</td>
<td>Person Information – I :
-CPI
-DOB
-Sex
-SS# (Assigned CPI)
-Adr1 (P F12 to accept address)
-Phone
-HIPAA NOPP
-Adv Dir
-Race
-Mar St
-VIP
-LANG
-RLG
-Spec Comm
-Ethnicity</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>
</td>
<td>Person Information - II:
-Email Address
-Emp Id #
-Occupation
-Name
-Status
-Effective From
-Adr 1
-Zip
-State
-City
-Phone
-Comments</td>
<td></td>
</tr>
</table>

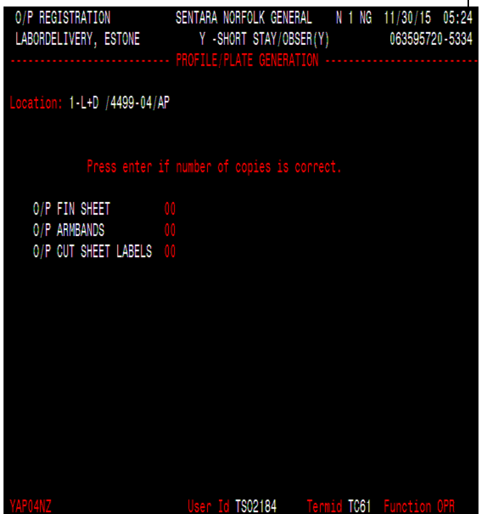
<table>
<tr>
<td>7</td>
<td>
</td>
<td>Advance Care Plan:
-Have you completed an Advanced Care Plan?
-Is your ACP new or update? (Y/N)
-Date last asked
-If YES ACP (Advance Directive)
1. Do you have your ACP with you? (Y/N)
*If No, Requested to bring? (Y/N)
2. Have you ever provided your newest ACP to Sentara? (Y/N)
-If NO ACP
1. Unable to collect due to Pt condition, F/U required… (Y/N)
2. Information given (Y/N/Refused).</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>
</td>
<td>Palm Scan Enrollment
-Enroll? (Y/N)
-Reason not enrolled</td>
<td></td>
</tr>
</table>

9		Visit history/ Suffix selection -Visit Suffix **Review the generated visit suffix, press enter to continue CPI update complete	
10		Guarantor Selection Parameters -Is the guarantor the same as the patient? (Y/N) -SS# -Last name, First name, Middle Name, Title, Suffix, Sex, Race, Birthdate (MM DD CCYY), Mom's Middle Name, State of residence. -CPI Number	
11		Nearest Relative Information: Name, Adr 1, Zip code, State, City, Phone, Rel to Patient Newborn Information Baby Bracelet #, Birth time **Guarantor set to patient	

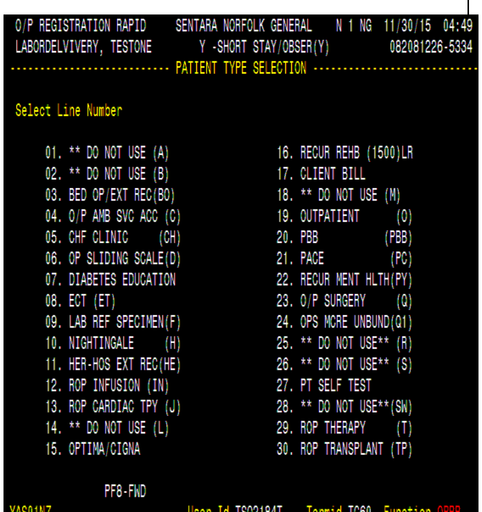
12		Emergency Contact Information Accident Information: Date, time, type, place, state, nature	
13		Insurance Company Selection: -Financial class, Effective date -Type any character to select existing plan -Other coverage not captured? (Y/R/E). Ins Comp Ind.. Note... To add new plans, type the character beside the insurance types: Mcare – Mcaid – BC –Comm – TRICARE - HMO	
14		Physician/Clinical: -Atn Physician -PCP/Fam Physician -Chief Complaint -Procedure Text	

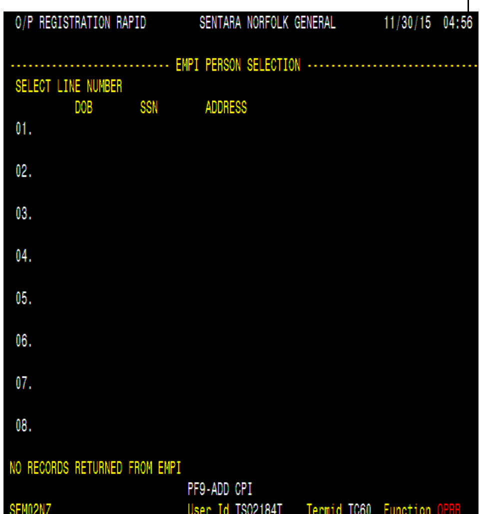
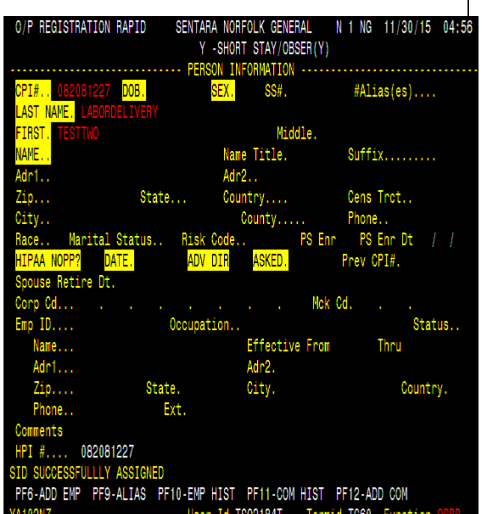
<table>
<tr>
<td>15</td>
<td>
</td>
<td>-Comments
-Notes from eCare</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>
</td>
<td>Visit Specific Outpatient:
-Scheduled Or Visit Date
-Visit Type
-Visit Source
-Hospital Service
-Military Srv rlt
-Infor release ind
-Location
-Re-registration date</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>
</td>
<td>Visit Specific Outpatient

**Scheduled or visit date is required</td>
<td></td>
</tr>
</table>

18		Profile - Plate generation	

APPENDIX B: OPRR FUNCTION DESCRIPTION

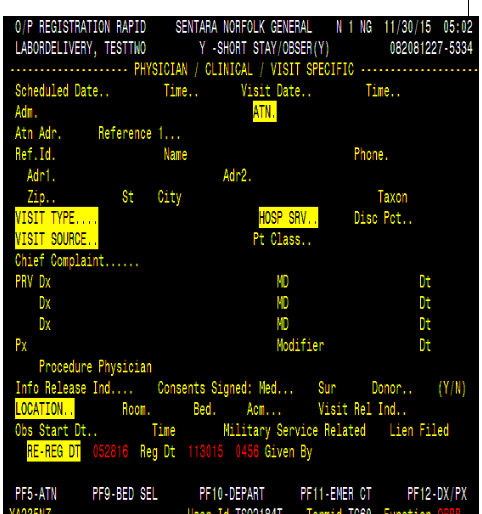
OPRR – Improved Methodology			
Screen Number	**Image**	**Fields**	**Standard Time**
1		Patient type selection	

<table>
<tr><td>2</td><td>
</td><td>Patient Selection Parameter:
-Patient name
And/or
-Log date</td><td></td></tr>
<tr><td>3</td><td>
</td><td>Select and existing record: SSN and Address</td><td></td></tr>
<tr><td>4</td><td>
</td><td>Person Information: CPI,DOB, Sex, SS#, First Name, Last Name, HIPAA NOOP, ADV DIR

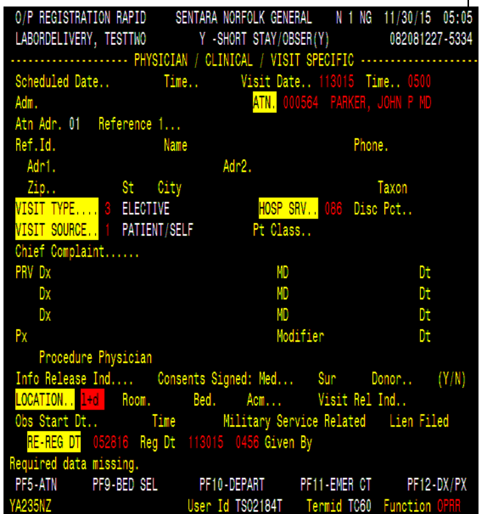
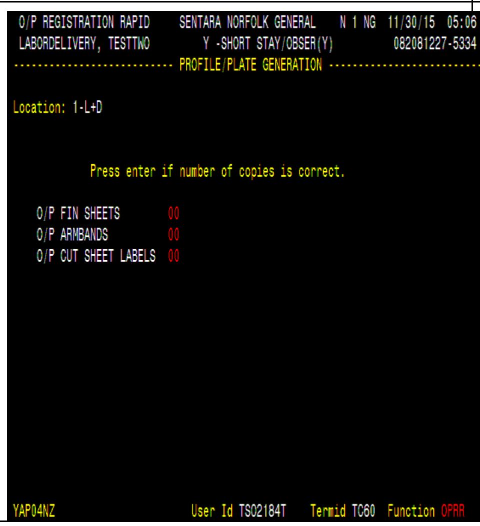
Note: CPI and SS# are assigned by the system</td><td></td></tr>
</table>

<table>
<tr>
<td>5</td>
<td>


</td>
<td>Guarantor Selection Parameters
-Is the guarantor the as the patient? (Y/N)
-SS#
-Personal Information: Last name, First name, Middle Name, Title, Suffix, Sex, Race, Birthdate (MM DD CCYY), Mom’s Middle Name, State of residence.
-CPI Number</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>


</td>
<td>Insurance Company Selection:
-Financial class
-Effective date
-Select existing plan (Type character)
-Other coverage nor capture? (Y/R/E)
-Add new plan (Type character)</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>


</td>
<td>Information: Physician / Clinical/ Visit Specific (1)
-Scheduled or visit date
-Atn physician
-Visit type
-Hosp srv
-Visit source
Locations</td>
<td></td>
</tr>
</table>

8		Information: Physician / Clinical/ Visit Specific (2) - Required data missing	
9		Profile / Plate Generation	

VITA

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Old Dominion University

Norfolk, VA 23529

Educational Background

M.S.: May 2017, Old Dominion University, Norfolk, Virginia, USA
Major: Engineering Management
Thesis: *Impact of a Localized Lean Six Sigma Implementation on Overall Patient Safety and Process Efficiency.*

B.S.: May 2013, Universidad Centroamericana, Managua, Nicaragua.
Major: Industrial Engineering