LEAN THINKING EFFECTIVENESS IN HOSPITAL EMERGENCY DEPARTMENTS

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THESIS: LEAN THINKING EFFECTIVENSS IN HOSPITAL EMERGENCY DEPARTMENTS

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ABSTRACT

Emergency department overcrowding has exhibited an increasing trend, as described through the length of stay metric reported by hospital systems through the Centers for Medicare and Medicaid Services (CMS), a United States federal government program. This thesis explores the significance lean thinking provides to reducing this metric. Data retrieved from CMS is analyzed to establish an appropriate test statistic. Results from the independent t-test suggest no significant difference in length of stay in response to utilizing lean thinking. Recent data does not support lean thinking as an effective tool to reduce length of stay to alleviate overcrowding in the emergency department. This thesis adds to the lean thinking body of knowledge by providing an analysis of the effectiveness of lean thinking across emergency department healthcare systems, from which improvements in lean thinking implementation may be measured against.

CHAPTER 1

INTRODUCTION

Background

The success of any business ultimately comes down to how well they satisfy their customers. If a business is in touch with their customers' needs and wants, and meets or exceeds customer expectations, the business has positioned itself for success. A business which is indifferent to the thoughts and feelings of their customer will be at a disadvantage to those competitors that provide better goods and services. Business relies on customers' perceived value of their products and services for sustainability. Customers have specific needs: products and services that deliver specific abilities and capacities at fair market prices. The customer determines the quality of the experience based on whether or not these needs have been met, and to what extent, which defines customer satisfaction. Customer satisfaction data has been collected for decades by hospital emergency departments in order to meet requirements such as repayment by government agencies and for patient experience improvement initiatives.

Alijani, Kwun, Omar, and Williams (2015) measured customer satisfaction across six hospital emergency departments in New Orleans. Their results suggest a majority of customers did not find value with emergency department services, including doctors, nurses, and administration staff. When a teaching hospital implemented systemic changes to improve customer satisfaction, Spaite et al. (2002) observed a decrease in length of stay and improvements in patient satisfaction. Length of stay is measured from the time the patient enters the emergency department to the time they are discharged. After analyzing hospital data from Ontario, Canada, between 2002 and 2007, Guttmann et al. (2011) suggest prolonged length of

stay contributes to adverse or less effective patient outcomes. These examples demonstrate the importance of the length of stay attribute. As this time increases, it is suggested that customers are increasingly dissatisfied and receive less than optimal care.

To understand the scope of increasing length of stay, Wilper et al. (2008) analyzed data obtained from National Hospital Ambulatory Medical Care Survey (NHAMCS) from 1997-2000 and 2003-2004. Hospital systemic factors have been suggested to contribute to increased length of stay, which may contribute to overcrowding and delays in providing care (Horwitz, Green, & Bradley, 2010). National length of stay statistics report 48% of emergency departments (EDs) admitting more than 90% of their patients within six hours, and only 25% of EDs admitting more than 90% of their patients within four hours. Across hospitals, variation in length of stay was hospital dependent. After multivariate analysis, a significant amount of variation was not accounted for in the study.

Increased customer demand and limiting resources are two factors which may contribute to overcrowding. As more patients enter the ED without diversion to inpatient status, access to emergency care is constrained. This may lead to adverse effects and reduced quality of care. The Institute of Medicine (2007) published a multi-year investigation describing the complex issues present in the healthcare industry, and suggestions to remedy ED overcrowding, which was described as a national epidemic. Overcrowding may be the result of the ED becoming a “safety net” where primary care services are now being provided in addition to emergency care.

EDs are legally bound to receive and treat all who enter their facility. Underinsured and uninsured population segments may now be using the emergency department for primary care as they do not have access to traditional primary care physician services. Other factors identified within this investigation that may contribute to overcrowding are U.S. population growth of

12%, 26% increase in emergency department visits, and the net loss of 713 hospitals and 425 hospital emergency departments. For the purpose of this thesis, overcrowding is described as a condition in the emergency department where the number of patients seeking medical care exceeds capacity. Given the types of interventions that are provided to patients and the limited number of beds, the emergency department can provide care to a finite number of patients within a specified timeframe. When the available bed constraint is met, patients wait. As more people enter the emergency department seeking care, more people wait. Waiting adds to the patient's length of stay in the emergency department. From a lean thinking perspective, waiting is non-value-added time portion of throughput time.

The term lean thinking is a description introduced by Womack and Jones (2003) after studying the Toyota Production System. There is inherent waste of resources built into any process. Lean thinking is an approach which identifies the waste of resources and removes or reduces the resource waste from the process. As waste is built into a process, the customer pays for this waste. Removing waste reduces the cost to the customer as well as the business. Wait and transportation time, as well as inefficient use of labor are a waste of resource. In *Lean Thinking* (2003), the authors present five guiding principles that contribute to the success of the Toyota Production System, which may be reproduced towards the success of most business ventures: specify value for the customer, identify value streams for each product or service, create a continuous flow process, produce as the customer requires it (pull value), and perfection (Womack & Jones, 2003, p. 15-101). For this thesis, value for the customer is described as timely and effective care. The timelier the service, the more effective the treatment. The second principle of identifying value streams for each product or service provides incentive to map out each process and display facts on the map relative to timeliness and effectiveness of care. Instead

of the common practice of batch production, which has been found to lead to increases in time and material resource waste, the third principle of continuous flow is explored. Introducing continuous flow in the context of this thesis is described as the patient moving from step to step by being directly handed off from the current process step owner to the next process step owner. Complementing the continuous flow principle is the pull value principle. For example, to achieve pull value, the nurse that provides patient assessment and assigns a bed reaches out to the previous process step owner (triage nurse) for the next patient. To this end, the patient inventory and wait time between process steps is significantly reduced or eliminated. Finally, the principle of perfection is repeating the cycle until waste elimination or maximal reduction is realized.

There are several metrics utilized in lean thinking that provide focus for the value stream manager on where to implement improvements in the process, such as takt time, cycle time, and throughput time. A value stream manager is an individual who has been afforded responsibilities and authorities to ensure successful implementation of the lean thinking initiative within the organization. Takt time is calculated by dividing the net production time by customer demand. Net production time is the time in which material or service can be produced (e.g., eight-hour shift) minus time for breaks, lunch, meetings, and any other time that is not directly spent operating within the process. Customer demand is the number of items the customer requires within a given timeframe. Takt time is a metric that describes process value in terms of customer. Cycle time is calculated by dividing the net production time by the number of units produced and describes process value in terms of the business. A business goal is to achieve a cycle time equal to takt time. If this is not achieved, review of the current value stream map should afford focal points for improvement initiatives. Throughput time is calculated by adding the time required for each process step, inspection time, transportation time, and wait time. All five principles impact

throughput time. Throughput time is the focus of this thesis and is described as the total time it takes the emergency department to completely serve a customer.

The value stream map is an extension of the second principle and is a visual aid which presents details of the process, including takt time, cycle time, inventories, and throughput time. In *Learning to See* (2003), production of value stream maps is described (Rother & Shook, 2003, p. 9). For a given service, a current value stream map is produced which maps out each step in the process. Each step lists, amongst many details, the time it takes towards completion. This map also details the time and inventory count in between each step in the process, and the throughput time. This map is then analyzed for opportunities to reduce the resources used in the process. Proposed improvements are then drawn in a future state map which may include combining or eliminating process steps as well as presenting new takt, cycle, wait, transportation, and throughput times. *Learning to See*'s (2003) introduction presents the lean thinking practitioner with a guide to map out the process from the time the material or customer enters the business to the time the product or customer leaves the business (Rother & Shook, 2003).

The value stream for the customer does not necessarily start or at the doors of this business. Often, there are suppliers of components upstream and providers of finished goods downstream of the business. This requires an extended view of the value stream. *Seeing the Whole Value Stream* (2011) extends the view the value stream map beyond the doors of the business (Womack & Jones, 2011, p. 4-5). In context of this thesis, the extended value stream begins at the patients' home or business, extends into the emergency department, then the hospital proper, rehabilitation facilities and even long-term care facilities, all of which contribute to length of stay. For example, a robust communication between the patient and their primary

care physician should present preventive health care activities that minimize illness and disease processes. These activities should reduce the resources needed in the event of emergent care. Another example is by improving patient flow in the hospital, beds will be more readily available for those patients in the emergency department, thereby reducing emergency department length of stay. For this thesis, health care length of stay is synonymous to lean thinking throughput time. An understanding of how to draw value stream maps will be invaluable when discussing explanations of the results, summary and conclusions presented in this thesis.

The length of stay data presented in this thesis is obtained from United States Centers for Medicare & Medicaid Services (CMS), a federal government agency. This agency operates an internet website encouraging patients to make the best decisions regarding their health care by working with their doctors. This is facilitated by providing the consumer-patient with information regarding quality and cost. CMS supports patient-centered care by health care providers in their pursuit of quality improvement, accessibility, and cost using new technology.

Hospital Compare is a website within the CMS website that is presented for use by the consumer, providing information on the effectiveness of patient care by health care providers. This website allows consumers to make multiple health care provider selections and compare performance measures such as timely and effective care to make informed decisions as to which health care provider to choose. Hospital Compare originated in response to stakeholders promoting the reporting of hospital quality of care, providing an information gateway for consumer decision-making. The presence of Hospital Compare promotes a competitive marketplace. This competition is the driving force behind innovation and quality of care improvement initiatives to attract consumers.

Hospital Compare has continuously strived to improve services. Notably in 2008, the Hospital Consumer Assessment of Healthcare Providers and Systems (HCAHPS) survey was added. This standardized data collection instrument provides health care measures based on the patient's perspective. In 2009, emergency department health care measure data was added. Quality measure data is continuously updated to provide the consumer with the latest information for decision making. This website was used as the source for the length of stay data presented in this thesis. Length of stay is a metric found within the timely and effective care data set.

Length of stay data presented in this thesis is procured from CMS Hospital Compare. As this government data is in the public domain, permission for its use is not required. Government endorsement or approval is not implied upon presentation of this thesis. This thesis is a systematic investigation testing the effectiveness of lean thinking in the emergency department setting based on throughput time as measured by length of stay. An intent of this thesis is to contribute findings for use by other professionals. The gathering of data and subsequent calculations performed in this thesis did not include communication or interpersonal contact between this author and CMS, American Hospital Association (AHA), any emergency department, or human subject. Length of stay data procured from the CMS Hospital Compare timely and effective care data set does not include individually identifiable private information, and there was no possibility of identifying a living individual at any point during the production of this thesis.

Statement of the Problem

As a result of increased length of stay, overcrowding has become an issue adversely affecting patient care and satisfaction in the emergency department setting (Mullins & Pines,

2014; Wang et al., 2017; Allaudeen et al., 2017; Chang et al., 2017). The issue of overcrowding within the context of this thesis is described as a condition in the emergency department where the number of patients seeking medical care exceeds capacity and is additionally compounded by an increase in demand for emergency department services in conjunction with a decrease in facilities (Institute of Medicine, 2007). Given that overcrowding is attributed to length of stay has employment of lean thinking in an emergency department setting improved an undesirable length of stay metric? Lean thinking is a quality improvement tool designed to view the production of material and services in terms of customer value. From this view the business identifies value added steps and non-value-added steps and reduces or removes those non-value-added steps.

Of the many areas in which improvements may occur from lean thinking, Womack (2003) states a potential throughput time reduction of 90%. In the context of this thesis, the term throughput time is the amount of time it takes for one patient to go through all the steps in the emergency department health care process and is synonymous to the term length of stay. A throughput time reduction of 90% would present a significant reduction in length of stay, thereby reducing the overcrowding problem. Have these outcomes been realized for those hospital emergency departments which employ lean thinking? If so, one could expect emergency departments employing lean thinking to report a length of stay metric significantly different from the emergency departments which do not identify as employing lean thinking.

Hypothesis: Emergency departments employing lean thinking will score a significantly lower median length of stay metric than emergency departments not identified as using lean thinking.

Purpose of the Study

The purpose of this thesis is to evaluate the effectiveness of lean thinking in hospital emergency departments based on throughput time as measured by length of stay. All studies reviewed by this author concerning hospital emergency departments employing lean thinking have provided post-implementation data that describe significant improvements in length of stay compared to pre-implementation data. The hospital systems that employed lean thinking did so in response to observations identifying a standard of care that did not meet their organizational expectations.

This thesis seeks to compare the length of stay metric for emergency departments which have been identified as using lean thinking to emergency departments which have not been identified as using lean thinking. Through this comparison, inferences may be determined between lean thinking emergency departments and emergency departments which have not been identified as using lean thinking. These inferences will support or refute the hypothesis of this thesis. This thesis supports the studies by Allaudeen et al. (2017), Chang et al. (2017), Mullins and Pines (2014), and Gabow and Mehler (2011) in that the work by each of these authors focuses on one or more of the central themes of length of stay, overcrowding, throughput, the use of AHA to identify health care systems, the use of data obtained from CMS Hospital Compare, statistical analysis of data, and lean thinking. This thesis makes use of each of these themes. Furthermore, the works of Chang et al. (2017) and Mullins and Pines (2014) make comparisons amongst hospital systems. This thesis differs from the works of Allaudeen et al. (2017) and Gabow and Mehler (2011) as these authors produced statistical analysis of outcomes including length of stay from one hospital system. This thesis expands upon the knowledge forwarded by

Allaudeen et al. (2017), Chang et al. (2017), Mullins and Pines (2014), and Gabow and Mehler (2011) by providing an analysis of the effectiveness of lean thinking on the length of stay attribute compared to other hospital systems which have not been identified as employing lean thinking.

Theoretical Bases and Organization

This thesis investigates whether overcrowding in emergency departments can be addressed through the employment of lean thinking within their quality systems. Increases in emergency department length of stay contribute to overcrowding (Mullins & Pines, 2014; Wang et al., 2017; Allaudeen et al., 2017; Chang et al., 2017). Overcrowding has been described as a condition which interferes with providing quality care (Institute of Medicine, 2007). Length of stay in the context of this thesis is described as a measure of time in which a patient moves through the emergency department process. Therefore, length of stay is an appropriate statistic for use in this thesis. This thesis uses the AHA website as a source to identify emergency departments, similar to Chang et al. (2017). Length of stay data was obtained from CMS Hospital Compare, similar to Chang et al. (2017) and Mullins and Pines (2014). Based on the use of information from AHA and data from CMS Hospital Compare by the cited studies, this thesis is constructed to obtain information and data from these sources.

This thesis establishes a lean thinking treatment group through identification from the AHA website, obtains length of stay data from CMS Hospital Compare, and analyzes the length of stay statistic between the treatment group and a non-treatment group. For the purpose of this thesis, a lean thinking treatment group is a finite sample of emergency departments which have been identified through an AHA search as employing lean thinking to address length of stay. The non-treatment group is a finite sample of emergency departments which have not been identified

through an AHA search as employing lean thinking to address length of stay. This thesis follows the theories that overcrowding reduces quality of care, that length of stay is a major factor in overcrowding, and application of lean thinking may be an effective remedy to reduce length of stay. This thesis intends to evaluate the effectiveness of lean thinking in the emergency department setting through the reported length of stay metric as a measure of throughput time. This approach is similar to Allaudeen et al. (2017) and Gabow and Mehler (2011).

Limitations of the Study

The sample hospital group (n=7) that has lean thinking treatment range in date of first implementation from 2005 to 2012. This thesis does not validate whether these facilities are still employing lean thinking. Validating the use of lean thinking by emergency departments is outside the scope of this thesis and will not be addressed. Length of stay data from CMS Hospital Compare represents a population. The treatment group and the non-treatment group data are both extracted from this population. The population obviously includes lean thinking ED facilities and may also include other ED facilities utilizing other quality improvement schemes, or no improvement scheme at all. In this regard, the population emulates the ambiguity observed with the lean thinking treatment group. Using a population that has been determined to have a non normal distribution presents a challenge when inferring about the difference between two independent means. Using value stream maps, the lean thinking practitioner gains insight as to where to focus improvement efforts to reduce or eliminate resource wastes. Presentation of value stream maps and improvement schemes or tools that may be used toward this end are outside the scope of this thesis and will not be addressed.

Definition of Terms

American Hospital Association (AHA): A national nonprofit professional organization that represents hospitals as well as health care networks, systems, institutions, and individual members. The organization serves its members through advocacy and support towards improving delivery of care to patients and communities by providing benchmark leadership, administrative, change management, data driven market research and decision-making strategies, tools and processes.

Centers for Medicare & Medicaid Services (CMS): A federal agency that administers Medicare, a federal program. This agency also partners with state governed health agencies in the administration of Medicaid. Medicare is a national health insurance program provided to American citizens over the age of 65. Medicaid is also a health insurance program provided to American citizens that have limited financial means.

Continuous flow: The production of one piece at a time, moving from one work station to the next without interruptions or delays. Each work station is synchronous with the immediate upstream and downstream work station. Each work station operator delivers a piece to the downstream operator just as they are ready to receive it and receives the next piece from the upstream operator. This prevents costly inventory build-up, slow-downs in production, and the necessity for storage space.

Current state map: this is a process map, with specific data detailing current business practices relating how long process steps take, how much time is spent between process steps, how much material is processed at each step and how much inventory is waiting for the next process step, how many operators it takes for each process step, and how material and information flows within the process.

Customer satisfaction: a measurement performed by businesses describing the effectiveness of business efforts in establishing a beneficial relationship with a customer, meeting and exceeding customer expectations, and the degree in which the business is valued by the customer when the customer makes a purchasing decision.

Customer value: the intrinsic usefulness or benefit of a product or service to the user. The product embodies a set of attributes which appeals to the customer, driving customer satisfaction, customer loyalty to the business, and profit for the business.

Cycle time: a measurement in seconds of the duration from the moment material is delivered to a process step to the moment it is released from the process step.

Emergency Department (ED): a facility which admits people requiring health care, providing interventions or stabilizing body systems for treatment from more specialized medicine.

Future state map: this is a process map, with specific data detailing projected outcomes from proposed business process improvements.

Ideal state map: this is a process map, with specific data detailing projected outcomes from proposed business process improvements achieved after realization of extended future state 1 and 2 map.

Lead time: a measurement in seconds of the time it takes one item to travel between process steps.

Lean thinking: a term which describes the Toyota Production System. It is an approach towards identifying and eliminating the inherent waste in a process.

Length of stay: a unit of time measured from the moment a customer enters to the moment they leave the emergency department.

Non-value-added time: a measure of time which the customer pays for but does not receive any benefit. For example, the time a patient spends waiting for a doctor examination is of no benefit to the patient and is considered non-value-added time.

Overcrowding: this is a condition in which the volume of customers exceeds the capacity of healthcare professionals to treat in a timely manner. This results in customers waiting for treatment, which in turn presents opportunities for adverse healthcare outcomes.

Production lead time: a measurement in seconds of the time it takes one item to travel from the first process step through the last process step.

Pull value: when an upstream process step produces only the amount needed at the next downstream process step, when it is needed.

Takt time: a metric describing the pace of the process. It is calculated by defining the available working time per day in seconds and dividing this number by the rate of customer demand per day.

Throughput time: the amount of time it takes for one item (patient) to go through all the steps in the process, including the production, inspection, transportation and wait times.

Value-added time: a measure of time which directly benefits the customer. For example, the time a doctor spends examining a patient benefits the patient and is considered value-added time.

Value stream: all actions required to design a product, produce the product starting from raw materials, and deliver the finished product to the customer. This overarching view of the complete production process provides opportunities to improve the system; the producing parts of the process as well as the linkages between these parts.

Value stream manager: an individual who is given responsibility of creating current and future value stream maps and responsible for implementing plans that realize the future value stream.

This person has been invested with authority to cross inter- and intra-organizational boundaries to make change happen; monitors, maintains and updates lean implementation; makes implementation their top priority; and reports only to the on-site top authority.

Value stream map: this is a process map that follows the flow of material and information as the product is transformed from raw material into finished good. It is a visual graphic that serves as a baseline from which common understanding is drawn amongst all participating team members and stakeholders.

CHAPTER 2

LITERATURE REVIEW

Many research studies were reviewed that helped establish correlations between use of lean thinking, length of stay, safety, efficacy, and customer satisfaction. Four of these articles will be presented here, "Using Lean Management to Reduce Emergency Department Length of Stay for Medicine Admissions" (2017), "Associations of Emergency Department Length-of-Stay with Publicly Reported Quality-of-Care Measures" (2017), "National ED Crowding and Hospital Quality" (2014), and "A Broad and Structured Approach to Improving Patient Safety and Quality" (2011) (Allaudeen et al., 2017; Chang et al., 2017; Mullins & Pines, 2014; Gabow & Mehler, 2011). This thesis does not perform research on humans or human behavior. This thesis evaluates lean thinking within emergency department quality systems and is based upon the findings of these research studies presented in this literature review. The primary sources that provide a working knowledge of lean thinking as well as other articles and research studies used to develop this thesis are listed in the references.

Allaudeen et al.'s (2017) study was performed at a university affiliated Veterans Affairs (VA) emergency department medical center from February 2013-2016. Allaudeen et al. (2017) studied increasing length of stay for those patients subsequently admitted into the hospital for treatment and the adverse consequences of this growing situation on emergency department operations, clinical outcomes, and patient satisfaction. Results of this quality improvement intervention is a decrease in length of stay of 26% and a decrease of seven-tenths of an hour for combined medical and surgical admissions compared to no change measured at VA sites not incorporating lean initiatives.

This study was very helpful as an example of the effectiveness of lean thinking when applied at a system level operation. The study is also an example of the ongoing and current overcrowding problem that emergency departments face that result in growing length of stay for the customers. The project utilized the five principles of lean thinking in order to improve workflow. The study does not provide details, but it does specify the use of workshops to train stakeholders in lean thinking. The study is an example of the ongoing problem of patient throughput and can be used in the problem statement.

The work presented by Allaudeen et al. (2017) provides evidence lean thinking applied in a health care setting is effective. It supports this thesis, as it considers length of stay, adverse outcomes when this time increases, and patient satisfaction. The work presented by Allaudeen et al. (2017) analyzes the length of stay metric before and after implementation of lean thinking only at the one VA emergency department. In contrast, this thesis analyzes the length of stay metric between emergency departments that have been identified as using lean thinking and emergency departments which have not been identified as using lean thinking. Additionally, this thesis produces the lean thinking non-lean thinking groups using independent processes.

In Chang et al.'s (2017) study utilized 2012 and 2013 data from the AHA, CMS Cost Reports, and CMS Hospital Compare consisting of over 2,600 U.S. hospitals to study the effects of emergency department length of stay on patient satisfaction. The study describes for each additional hour in length of stay, a 0.7% decrease in patients giving a top performance rating was observed as was an increase of 44% that the patient leaves without being seen. This action often leads to adverse consequences.

This was a comprehensive study at an industry level perspective performed in 2017. This strongly suggests crowding, timeliness of care, and length of stay are current problems

emergency departments face. This study listed the data sources CMS Cost Reports and CMS Hospital Compare and six measures representing quality of care, covariate analysis on hospital level characteristics to rule out independent sources of variation, and linear regression to test relationships between quality of care outcomes with length of stay. This is a study that focuses on length of stay and quality metrics using publicly reported data at a national level. The study is an example of the ongoing problem of patient throughput and can be used in the problem statement.

The work presented by Chang et al. (2017) supports the theoretical background for this thesis. Data from the AHA and CMS Hospital Compare were used to analyze the relationship between emergency department length of stay and customer satisfaction. It differs from this thesis in that the work presented by Chang et al. does not explore improvement initiatives such as lean thinking and their effect on length of stay.

Mullins and Pines' (2014) study compared performance, crowding, and other quality metrics of media-ranked hospitals to unranked hospitals emergency department data for 2012. The data source was Hospital Compare released in 2013. The crowding metrics were: left without being seen, wait time, boarding time, and length of stay for admitted and discharged patients. The study reported poorer performance from the ranked hospitals than unranked hospitals. The study found great variation in crowding metrics across the sample population of 4,810 hospitals, suggesting variation is likely hospital dependent and not patient dependent.

This study supports the research already present in this field. This study employed a straightforward methodology and statistical comparison. The study was organized and presented logically. The study is a primary source, but dated 2014. The study is an example of the ongoing problem of patient throughput and can be used in the problem statement section of this thesis.

The work presented by Mullins and Pines (2014) uses data obtained from Hospital Compare supporting the use of this data source for this thesis. Mullins and Pines (2014) compares crowding metrics between ranked and unranked hospitals. Please note length of stay is identified as one of the crowding metrics. The work presented by Mullins and Pines (2014) analyzes the length of stay metric between emergency departments that have been identified as media-ranked and emergency departments that have not been identified as media-ranked. Mullins and Pines (2014) investigative design supports the theoretical basis for this thesis. The work presented by Mullins and Pines (2014) focused on national ranking whereas this thesis focuses on length of stay. As previously stated, the study reported poorer performance from the media-ranked hospitals than unranked hospitals. It does not consider quality improvement initiatives, such as lean thinking, nor the effectiveness of any such initiative. The work by Mullins and Pines (2014) is used as a framework in which to construct this thesis.

Gabow and Mehler's (2011) study employed lean thinking and kaizen events identifying over sixteen value streams. More than 300 rapid improvement events occurred between 2007 and 2011. Some specific process outcomes have improved, but system level improvements had not been affected. The business lacked a scientific approach to achieve institutional quality and safety. Denver Health is an integrated system, utilizes an employed-physician model, and is a leader in the use of information technology. Their quality improvement approach involved four steps: It must be comprehensive, there must be a quality department to oversee initiatives, must create programs to manage risk and opportunities, and must implement systems to reduce variability in patient care.

Results are ranking from 28th in the university health system consortium quality and accountability aggregate score in 2008 to first in 2010. Mortality rate is now the lowest in

Colorado, which is 26% lower than would be expected for a facility with its case mix. Cesarean section rate has been the lowest of all consortium hospitals for two years with no full-term fetal mortality. In 2010, Denver health had two sentinel events, compared to nine in 2009 and 13 in 2008.

The study described the problems and the areas in which to apply solutions. It could have included more detail on the specific quality initiatives and use of figures like some bar graphs of before implementation and after for key performance indicators. The study provides evidence that system-wide lean thinking leads to operational success in the healthcare setting and is sustainable. This is a primary source, but from 2011. The study is an example of how using lean thinking leads to success and can be used in the theoretical bases section of this thesis.

The work presented by Gabow and Mehler (2011) supports the use of lean thinking to improve health care systems towards the benefit of both the customer and the business and is relatable to other studies on the effectiveness of lean thinking in a health care provider setting. The work presented by Gabow and Mehler (2011) analyzes operational success outcomes before and after implementation of lean thinking only at the Denver Health emergency department. In contrast, this thesis analyzes the length of stay metric between emergency departments that have been identified as using lean thinking and emergency departments which have not been identified as using lean thinking. Additionally, this thesis produces the lean thinking non-lean thinking groups using independent processes.

Several key categorical themes surfaced as a result of this literature review. The length of stay metric has been established as a factor in overcrowding. Overcrowding has been identified as a serious impediment towards providing emergency quality of care (Allaudeen et al., 2017; Chang et al., 2017; Mullins & Pines, 2014). For this thesis, overcrowding is described as a

condition in the emergency department where the number of patients seeking medical care exceeds the capacity of the emergency department to provide timely health care services. When capacity is met, patients wait. As more people enter the emergency department seeking care, more people wait. Waiting adds to the patient's length of stay in the emergency department. Emergency department length of stay is defined in this thesis as a unit of time measured from the moment a customer enters to the moment they leave the emergency department (Allaudeen et al., 2017; Chang et al., 2017; Mullins & Pines, 2014). From a lean thinking perspective, the act of waiting by the patient and transportation of the patient between process steps contribute to non-value-added time portion of throughput time. Non-value-added time is a measure of time which the customer pays for but does not receive any benefit. For this thesis, throughput time is defined as the amount of time it takes for one patient to go through all the steps in the emergency department process. Please note the emergency department term length of stay is synonymous with the lean thinking term throughput time within the context of this thesis. The employment of lean thinking in an emergency department setting has produced measurable improvements in throughput time resulting in improved customer satisfaction (Allaudeen et al., 2017; Gabow & Mehler, 2011). The AHA is a reliable source for identifying hospital systems (Chang et al., 2017). Finally, CMS Hospital Compare is a reliable source of publicly available hospital data. Chang et al. (2017) and Mullins and Pines (2014) utilized data obtained from CMS Hospital Compare. Each of these themes were used to construct the theoretical bases for this thesis.

The purpose of this thesis is to evaluate the effectiveness of lean thinking in hospital emergency departments based on throughput time as measured by length of stay. The problem statement of this thesis is: given that overcrowding is attributed to length of stay, has employment of lean thinking in an emergency department setting improved an undesirable length

of stay metric? The hypothesis presented in this thesis testing if lean thinking has improved the length of stay metric is: emergency departments employing lean thinking will score a significantly lower median length of stay metric than emergency departments not identified as using lean thinking. The purpose and problem statement presented in this thesis are in alignment with Allaudeen et al. (2017) and Gabow and Mehler (2011) where lean thinking was employed by an emergency department to address the length of stay metric which did not meet their organizational expectations.

CHAPTER 3

METHODOLOGY

Design of the Investigation

The relationship between length of stay to customer satisfaction has been established. Each facility employing lean thinking list significant improvements in this dependent variable when comparing lean thinking pre-implementation to post-implementation. Lean thinking is a description introduced by James Womack and Daniel Jones after studying the Toyota Production System and is an approach which identifies the waste of resources and removes or reduces resource waste from processes following five guiding principles. This thesis asks if the median length of stay metric for emergency departments employing lean thinking is significantly different than emergency departments which have not been identified as employing lean thinking.

This thesis analyzes the length of stay metric between emergency departments that have been identified as using lean thinking and emergency departments which have not been identified as using lean thinking. Additionally, this thesis produces the lean thinking and non-lean thinking groups using independent processes. This analysis was selected as it provided a simple framework to test a single treatment amongst two samples from a single population. Identification of the treatment group and non-treatment group was conceptualized using the same framework employed by Mullins and Pines (2014). The first step in formulating this thesis is to identify the variables. Length of stay is the dependent variable. The treatment is lean thinking. The independent variable is the emergency department. By manipulating the independent variable (emergency department) with the treatment (lean thinking), it is hypothesized that there

will be a statistically significant difference in the length of stay dependent variable between the lean thinking emergency department treatment group and the emergency department group that has not been identified as employing lean thinking. The second step is to describe the principle characteristics of the population, the treatment group, and the non-treatment group. Then the sampling scheme will be described. The third step is to describe the sequence followed in collecting and tabulating the data. The fourth step will describe and explain how data were analyzed and the statistical treatments used. This will include descriptions of the three assumptions that must be addressed to select the appropriate inferential test statistic, the computer program used to produce descriptive statistics required to conclude the second assumption, the purpose and usefulness of tables for reporting and presenting descriptive statistics, a description and purpose for using Levene's test and one-way analysis of variance for concluding the third assumption, and a description and purpose for selecting the independent t-test inferential test statistic.

Population

The principle characteristics of the population under investigation are that they are all emergency departments that have reported length of stay data to CMS. Length of stay data presented in this thesis is procured from CMS Hospital Compare. As this government data is in the public domain, permission for its use is not required. Government endorsement or approval is not implied upon presentation of this thesis. This thesis is a systematic investigation, testing the effectiveness of lean thinking in the emergency department setting based on throughput time as measured by length of stay. An intent of this thesis is to contribute findings for use by other professionals. The gathering of data and subsequent calculations performed in this thesis did not include communication or interpersonal contact between this author and CMS, AHA, any

emergency department, or human subject. Length of stay data procured from the CMS Hospital Compare timely and effective care data set does not include individually identifiable private information, and there was no possibility of identifying a living individual at any point during the production of this thesis. The calendar range for data used in this thesis was reported by hospitals to CMS between October 1, 2016, and September 30, 2017.

The total population represents the full spectrum of possibilities with respect to improvement initiatives, from no improvement plan to lean thinking, Six Sigma, or other robust Quality Management System. The length of stay data set consisted of 3,806 entries (n=3,806). The lean thinking treatment group consists of emergency departments that report length of stay metrics to CMS and was produced through searching the AHA website. The identity of the members of this sample set was established through performing an all content search using the key word “Lean” at the AHA website. The AHA website was used as a source for identifying emergency departments based on the work of Chang et al. (2017). The AHA website home page advocates for advancing hospital and health system best practices but does not list any link that specifically identifies lean thinking as a quality improvement scheme. As Allaudeen et al. (2017) and Gabow and Mehler (2011) provide examples of emergency departments employing lean thinking, this author surmised there were other emergency departments that employ lean thinking.

The first possible solution to find whether emergency departments share lean thinking quality improvements with the AHA community was to use the search function in the top right corner of the AHA website home page. This “Lean” search provided 115 results. All entries were reviewed, and only those hospitals identifying as using lean thinking to address emergency department length of stay problems were selected to be included in the lean thinking sample set.

This process produced only seven entities (n=7): Advocate Illinois Masonic Medical Center, Memorial Hospital in Belleville, Illinois, Advocate South Suburban Hospital in Hazel Crest, Illinois, Franciscan Health Indianapolis, Saint Joseph Regional Health Center in Bryan, Texas, Mary Washington Hospital, Inc. in Fredericksburg, Virginia, and Johnson Memorial Hospital in Abingdon, Virginia. Including all lean thinking emergency departments identified in the AHA website search may be described as a use of convenience. Using other sources for identifying emergency departments that employ lean thinking was not considered. Also, the total number of emergency departments employing lean thinking found on the AHA website was not of a size that would require sub-sampling for analysis.

The non-treatment group consists of emergency departments reporting length of stay metrics and was produced from the entire population through random selection utilizing a random number generator. The random numbers available for selection ranged between one and 3,806 and used an appropriately equal sample size (n=7) to that of the treatment group. The non-treatment group did not include data from emergency departments employing lean thinking identified in this thesis. Random selection was chosen for producing the non-treatment group due to the size of the population (n=3,806). Any number between one and 3,806 have an equal opportunity to be chosen to participate. The non-treatment sample have not been identified from the AHA website search as employing lean thinking in the emergency department setting to address length of stay problems.

Treatment

Data was retrieved from CMS Hospital Compare as one comma-separated values (CSV) Microsoft Excel spreadsheet. Within this spreadsheet, the “Timely and Effective Care” dataset was identified as containing dependent variable data length of stay. Dependent variable length of

stay is identified as the average (median) time the emergency department takes to provide complete service to the customer. Length of stay data was obtained through CMS Hospital Compare similar to the works by Mullins and Pines (2014), Wang et al. (2017), Allaudeen et al. (2017), and Chang et al. (2017). Data were filtered to report values only for length of stay attribute that reported real numbers for all emergency department entries. This data was copied and pasted on a new tab of the spreadsheet, named "length of stay."

The identification of the lean thinking emergency departments from the AHA website included locations and addresses. The data obtained from CMS Hospital Compare also included this information. Length of stay data for the lean thinking sample set was produced by referencing the physical addresses of the emergency departments obtained from the AHA website to the CMS dataset, and filtered. Length of stay data for the non-treatment group was produced through random selection. With this procedure, two distinct sets of length of stay scores were tabulated.

Data Analysis Procedures

The first assumption of the data that must be concluded in order to determine the appropriate test statistic is whether the samples were established independently. The second assumption of the data that must be concluded requires descriptive statistics. Descriptive statistics were produced through the use of the data analysis tool within the Microsoft Excel spreadsheet. For the length of stay population, the input range included all scores. The bin range, or binary range, is a list of possible numbers that may occur in the input range. By entering the input and bin ranges in the data analysis tool and selecting "descriptive statistics" and an output destination, descriptive statistics are calculated and provided in a table format. Descriptive statistics include mean, median, range, kurtosis, and skew. Reviewing the means and medians as

well as the kurtosis and skew for the length of stay dependent variable provides a normal or non normal distribution determination.

This distribution determination is the second assumption of the data that must be concluded to determine the appropriate test statistic. In the event a population is found to be non normal, the raw scores will be ranked in descending order. Ranking scores will be performed using the rank function available in Microsoft Excel. Ranking data is a data transformation process. The data is sorted in descending order. The raw score is then replaced by its rank. Ranking data this way establishes rank-size distribution of the scores, which is an inverse cumulative distribution. This distribution describes a pattern of the data from which non-parametric inferential statistics may be performed. This reduces the risk involved with using non normally distributed data. Ranked scores will then be used in place of raw scores to establish homogeneity of variance and calculating the test statistic.

Descriptive statistics often require viewing summaries of the main points of the data set briefly, such as in tables. Summarizing data also allows discussions using the commonly accepted terms. In order to compare data sets using conventional descriptions such as measures of central tendency and variation, it is useful to present these values side by side in a table. Table rows are used as the values, and the columns are used to describe the discreet samples as seen in Table 1.

The mean, median, and mode are measures of central tendency and are terms describing the center of a data set, from different perspectives. The mean is an average, where the sum of all numbers is divided by the total number of discreet data points. The median is that number which appears in the middle of the data set, when all numbers are presented in a logical sequence. The

mode is the number which appears most frequently. Each of these terms describes measures of central tendency for the data set using a single value.

The range, variance, and standard deviation are measures of dispersion or variation, and are terms which describe the spread of data using a single value. The range is the difference between the smallest number from the largest number and describes the extent of the data set. Variance is a measure of the average distance a data point is from the mean. Standard deviation is a measure quantifying the variation within a data set and is calculated by taking the square root of the variance.

Measures of central tendency and measures of variation may be used together to describe the distribution of the data as normal or non normal. The normal distribution describes a data set in which the mean, median and mode are the same value. Also, the frequency of numbers decreases the further away from the mean, equally on each side of the mean. This is graphically described as a bell curve, where the data is symmetrical around the mean. That is to say, the mean is an inflection point where the two sides are mirror images of one another.

Skewness is a term which describes an asymmetrical curve. Data is described as negatively skewed if the mode is greater than the median, and the median is greater than the mean. Data is positively skewed when the mode is less than the median, and the median is less than the mean. Graphically, negatively skewed data will depict the mean to the right of the center of the X-axis. Positively skewed data will depict the mean to the left of the center of the X-axis. As skew increases either positively or negatively, the probability of a normal distribution data pattern decreases. The skew of a normal distribution will have a value of zero.

Kurtosis describes the tailing ends of a bell curve. The kurtosis of a normal distribution will have a value of zero. A data set with a value for kurtosis greater than an absolute value of

two is described as falling outside a normal distribution pattern, as the tailing ends hold more data. These tails consist of data that tend to be outliers, or outside a 95% confidence interval.

By presenting measures of central tendency, measures of dispersion, skew, and kurtosis, a data set may be described as either normally distributed, or non normally distributed. These are descriptive statistics. Determining whether the distribution of a data set is normal or not normal assists the researcher to select the appropriate test statistic to test hypotheses.

Establishing homogeneity of variances is the third assumption that must be concluded in order to determine the appropriate test statistic. Levene's test will be used to test for this assumption and is an inferential test statistic which tests the null hypothesis that variances are equal. This is a one factor analysis of variance, performed using the ANOVA function in Microsoft Excel. The resulting p-value (probability value) is compared to a chosen level of significance, and if it is determined to be less than the level of significance, the null hypothesis is rejected. This decision is based on the improbability that the differences in the two sample variances is due to randomness. In other words, the differences are significant, and the variances are determined to be not equal. The p-value is obtained by performing a one-way analysis of variance between the non-treatment group and the treatment group.

Using inferential statistics, the researcher may infer the properties of interest observed from a sample group to the population, with a degree of certainty. By collecting and analyzing a smaller data set, the researcher may operate with more limited constraints such as time, cost, and complexity. Through inference, the researcher may develop a sampling plan that mathematically represents a cross section of the entire population based on the total number of participants and the degree of confidence required for the analysis. Using inferential statistics allow the researcher to make a judgement of the probability the differences found between two samples

obtained from the same population are dependable. Hypotheses are used to measure whether the sample means are statistically different and infer the extent of the difference of their respective segment population means.

If normality is established, the independent t-test will be appropriate if variances are homogeneous. If variances are not homogeneous, but the sample sizes are equal, the independent t-test is still appropriate. If homogeneity of variances is not met and there are unequal sample sizes, the Welch t-test is the appropriate test statistic. If normality is not established, and homogeneity of variances is met, the independent t-test using ranked scores is the appropriate test statistic. If neither normality nor homogeneous variances assumptions are met, the Welch t-test using ranked scores is the appropriate test statistic.

Based on the findings of these three assumptions, the independent t-test or Welch t-test statistic will be selected, utilizing either raw data or ranked data. For the length of stay dependent variable, the null hypothesis tested assumes the median for the population sample is equal to the treatment sample (H_0: $\mu_1 = \mu_2$) where μ_1 is the median for the population and μ_2 is the median for the treatment sample. If the test statistic *t* falls within the range listed in the *t* distribution table, the null hypothesis is not rejected. This finding would describe no difference between the population and treatment medians and would signify emergency departments employing lean thinking do not achieve statistically significant length of stay scores to those emergency departments which do not employ lean thinking. The independent t-test is performed by using the t-test function in Microsoft Excel.

CHAPTER 4

RESULTS AND DISCUSSION

This thesis provides an analysis of the median length of stay metric, comparing length of stay between an emergency department sample set employing lean thinking and an emergency department sample set not identified as employing lean thinking. Both samples reside within the same population, and data for this population was obtained from CMS Hospital Compare, a United States government agency website. This analysis provides a review of the effectiveness of lean thinking when applied to the emergency department setting. An investigation of this type was not found by this author when researching this topic for this thesis.

To determine the appropriate inferential test statistic, three assumptions of the data were concluded. The first assumption was to determine if the samples were obtained using the same method. The lean thinking treatment sample was produced though an all content search using the word “lean” on the AHA website. All results were reviewed, and those emergency departments which employed lean thinking to address length of stay were selected for inclusion in the treatment group. The non-treatment group was produced through random selection from the population of emergency departments which reported the length of stay metric to CMS. For purposes of convenience, the same number of emergency departments employing lean thinking were selected for inclusion in the non-treatment group. The non-treatment group was not identified from the AHA website content search as employing lean thinking to address length of stay. Thus, it has been concluded that the samples were produced independently.

The second assumption that was concluded is whether the data is normally or non normally distributed. Descriptive statistics were utilized to conclude this assumption. The

population mean time (141 minutes) was not equal to the median time (136 minutes). The kurtosis (2.344) falls slightly outside a range of an absolute value of two, signifying a sharper peak tailing than what may be considered normal for the distribution curve. Skewness (.983) falls within the range of an absolute value of two. Based on descriptive statistics depicted below in Table 1 Median Raw Scores for Length of Stay in Minutes, results indicate length of stay scores for the population may be reasonably considered to be non normally distributed. This finding establishes a determination for the second assumption required to select the appropriate test statistic.

Table 1

Median Raw Scores for Length of Stay in Minutes

Descriptive Statistic	Population Raw Scores	Treatment Raw Scores
Mean	141.3983184	177.1428571
Standard Error	0.677099618	14.03300289
Median	136	168
Mode	128	168
Standard Deviation	41.77216267	37.12783579
Sample Variance	1744.913574	1378.47619
Kurtosis	2.343842644	-1.44193833
Skewness	0.983462251	-0.155663978
Range	411	98
Minimum	49	124
Maximum	460	222
Sum	538162	1240
Count	3806	7

Based on a non normal population distribution determination, the raw scores were ranked in descending order. The ranked scores for the non-treatment group were copied onto one column in an empty section of the spreadsheet, and the ranked scores for the treatment group were copied onto an adjacent column to the non-treatment group. This data is depicted in Table 2 Ranked Scores for Length of Stay.

Table 2

Ranked Scores for Length of Stay

Non-Treatment Sample	Treatment Sample
3293	190
2116	858
459	159
764	858
1260	2363
1483	308
2187	1655

The third assumption of homogeneity of variances was concluded to select the appropriate inferential test statistic. Homogeneity of variance between the non-treatment ranked scores and treatment ranked scores was determined using Levene's test. The output from performing the analysis of variance (Levene's test) using the Microsoft Excel function is depicted in Table 3 Levene's Test Summary Information and Table 4 Levene's Test ANOVA Table. According to Levene's test, the homogeneity of variance assumption was satisfied (F = .2322, p = .638). The calculated probability value (p-value) is greater than the significance level (.05). Therefore, the null hypothesis that variances are equal is not rejected. The third assumption that variances are equal is determined.

Table 3

Levene's Test Summary Information

Groups	Count	Sum	Average	Variance
Column 1	7	5281.714	754.5306	267200.7
Column 2	7	4384	626.2857	228457.9

Table 4

Levene's Test ANOVA Table

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	57563.64	1	57563.64	0.232271	0.638515	4.747225
Within Groups	2973952	12	247829.3			
Total	3031515	13				

With results for the three assumptions, an independent t-test statistic was determined to be the appropriate inferential test statistic. In order to minimize the effects of Type I and Type II errors from using non normal data with the independent t-test, a two-tailed test was performed. As shown in Table 5 Ranked Score Descriptive Statistics for Length of Stay, both the non-treatment group and treatment group consisted of a sample size of seven (n=7), with a non-treatment sample mean of 1,651 (*SD* = 965.09) and a treatment sample mean of 913 (*SD* = 828.29).

Table 5

Ranked Score Descriptive Statistics for Length of Stay

Descriptive Statistic	Non-Treatment Ranked Scores	Treatment Ranked Scores
Mean	1651.714286	913
Standard Error	364.7706203	313.0641194
Median	1483	858
Mode	#N/A	858
Standard Deviation	965.0923469	828.2898044
Sample Variance	931403.2381	686064
Kurtosis	0.0085677	0.007526717
Skewness	0.574607299	0.997278585
Range	2834	2204
Minimum	459	159
Maximum	3293	2363
Sum	11562	6391
Count	7	7

The independent t-test indicated that the length of stay means were not statistically significantly different between the non-treatment group and the treatment group ($t = 1.5368$, $df = 12$, $p = .150$). The output produced by using the Microsoft Excel independent t-test function is depicted in Table 6 Independent t-Test for Ranked Length of Stay Scores. Thus, the null hypothesis that the length of stay means between the treatment and non-treatment samples was not rejected at the .05 level of significance. This result provides evidence that supports the conclusion that emergency departments employing lean thinking do not score a statistically significantly different median length of stay metric than emergency departments not identified as using lean thinking.

Table 6

Independent T-Test for Ranked Length of Stay Scores

Descriptive Statistic	Non-Treatment sample	Treatment sample
Mean	1651.714286	913
Variance	931403.2381	686064
Observations	7	7
Pooled Variance	808733.619	
Hypothesized Mean Difference	0	
Df	12	
t Stat	1.536766099	
P(T<=t) one-tail	0.075144562	
t Critical one-tail	1.782287556	
P(T<=t) two-tail	0.150289124	
t Critical two-tail	2.17881283	

This finding implies that lean thinking employed in emergency departments identified in this thesis is no more effective as a quality improvement tool to address length of stay, and more broadly overcrowding, compared to emergency departments not employing lean thinking. One explanation for this finding is the lean thinking initiative was not extended outside of the

emergency department. If lean thinking was extended into the hospital proper, bed availability may improve such that patients in the emergency department would experience reduced wait times for transfer. If lean thinking was extended into the general practitioners' offices, improved preventive care would reduce the number of people seeking health care and reduce the resources required for emergent care from the emergency department. If lean thinking was extended into long-term care facilities, improved care would reduce the number of admissions and re-admissions. With proactive approaches to quality of care, the number of people seeking treatment in the emergency department would be reduced. Improving the efficiency of patient transition from the emergency department into the hospital or a long-term care facility would also reduce length of stay and alleviate overcrowding.

There are many procedures and tests administered during the emergency department visit, such as computerized axial tomography (CAT) scans, X-ray scans, flu swabs and bloodwork laboratory tests for example. With a reduced patient occupancy as the result of extending lean thinking beyond the emergency department, the demand and subsequent waiting time for these tests and scans to be performed would reduce. This would in turn reduce length of stay and alleviate overcrowding.

CHAPTER 5

CONCLUSION

The growing cost of healthcare, the delivery of service, and its effectiveness have been of considerable concern in the United States at least since the 1990s. The United States population has grown, and the number of emergency department facilities has decreased. These factors as well as constrained access to preventive medicine from primary care physicians for underserved population demographics have produced consistent emergency department overcrowding. This has arguably led to poor timely delivery of healthcare services from emergency departments across the United States. Studies have described the effects of overcrowding as reduced quality of care and diminished customer satisfaction.

There are many aspects to quality of care. Timely delivery of service can be the difference between life and death, such as in cases like heart attacks and pneumonia. Patients waiting excessive time to see a healthcare professional are apt to become frustrated to the point that they leave. This may lead to their condition becoming more severe, costlier to treat, more time for recovery, and more resources to bear to provide care when finally administered. A hospital has limited resources. As resources become constrained, delivery of care is negatively impacted for all patients. Patients leaving without being seen compounds the overcrowding problem later, when they are likely admitted as the result of emergency transport. In this sense, they have visited the emergency department twice, whilst receiving treatment once. With constrained resources spread amongst the patient population, patients may wait longer for services such as nurse rounds, treatment such as delivery of medication, and diagnostic tests

performed. Overcrowding leads to increased inefficiencies, leading to increased patient dissatisfaction and negative healthcare industry publicity.

Hospitals and emergency departments that seek payment for services rendered to patients utilizing Medicare and Medicaid are required to report predetermined statistics to the CMS. The CMS also offers a public service called Hospital Compare, which allows the consumer to make informed decisions as to where they choose to obtain healthcare services. Unfortunately for many population segments, there is little to no choice when it comes to healthcare service providers. There may be only one hospital within 50 miles of the person that desperately needs service. Research has shown there are fewer hospitals today than there were twenty years ago. Rising cost of healthcare, poor patient economics, and health care systems' failure to meet regulatory requirements assuring government financial support may be a few of the many root causes for this situation.

There are many attractive components to lean thinking, which is described as an approach which identifies the waste of resources and removes or reduces the resource waste from the process. Driving improved customer value is a principle objective. Eliminating waste is another attractive result, which is directly relevant to operating cost. Lean thinking is realized through increasing productivity and decreasing time and resource excesses needed to produce material or a service. Lean thinking has shown to be effective in the manufacturing environment, and results such as these have induced many businesses in the service sector to adopt this quality improvement tool.

Many healthcare systems have been utilizing lean thinking for many years. As a business matures its lean thinking, success should build upon past successes. This is the continuous improvement engine that drives perfection. The presence of these mature lean thinking

organizations should provide data supporting the outcome of 90% decrease in throughput time stated by J. Womack (2003).

This thesis proposes a hypothesis to explore the decrease in throughput time utilizing industry data. Studies have suggested the longer a patient waits for service, and the longer the visit extends, the less effective treatment becomes and the less satisfied the patient becomes. The CMS reports the length of stay dependent variable which is pertinent to this thesis. The thesis hypothesis explores if there is a statistically significant difference in length of stay between emergency departments which have been identified as employing lean thinking and emergency departments which have not been identified as employing lean thinking. Through this analysis, effectiveness of lean thinking in the emergency department setting is evaluated within the context of the five principles that guide lean thinking.

Lean thinking employs five guiding principles. The first principle is defining customer value. In 2009, CMS established the reporting of emergency department health care measure data, including timely and effective care in which length of stay is a component. Within the context of this thesis, time is the stated value. The second principle is developing value stream maps. A current state map is a blueprint that lists statistics such as cycle time, lead time, throughput time and inventory data for example, that provide focus for the value stream manager. This current state map provides guidance to the lean thinking team by establishing common understanding of all actions necessary for the process to deliver the material or service to the customer, what actions bring value to the product and are important, the vocabulary which everyone will use when describing situations, and where to direct initiatives for improvements.

A future state map is then drawn from the current state map, listing sought after improvement outcomes in place of the current metrics. These proposed activities in turn help

establish project feasibility and priority, realistic and attainable goals, and a means to evaluate effectiveness of the projects when completed. Projects that reduce inventory and lead time will reduce non-value-added time to the process, thereby eliminating wasted time and resources. This will in turn reduce operating costs and increase profit margin. For financially challenged businesses, which many healthcare systems are, these potential results are desirable.

The third principle of lean thinking is producing flow value. Through the value stream map, tracing the flow of the product or service becomes obvious. Redundancies as well as process steps that have no purpose can be identified and eliminated. Producing in batches adds to inventory and exposure to risk due to changes in customer sentiment, leading to waste. Producing in batches also exposes the organization to scrap and rework, as defects are not detected before inventory build-up. Establishing flow value through production of one unit at a time with hand-off from one operator to the next eliminates inventory, and the process is more adaptive to changes in customer demand.

With this continuous flow, defects are more readily identified, and less scrap and rework are realized. This provides the business with more savings. Scrap and rework are all costs the businesses must absorb or pass on to the customer, which is not adding customer value. Continuous flow is the fourth principle and is a natural progression of the third principle, where pull value is established. With continuous flow, delivery is responsive to customer demand.

Downstream process steps pull the product or service from the preceding process step. This process step is now available to receive the part or service item from the preceding step, and so on. Every step in the process pulls the item along the process, as compared to the typical push system, where product is produced in batches at one step and then inventoried until the next downstream step is available to receive. Continuous flow eliminates or reduces between-process

inventories and transportation costs as well as contributes to meeting customer demand with little to no impact on work-in-process product.

The fifth principle of lean thinking is perfection. Once the future value stream is realized, the process is repeated utilizing what was learned, new technologies and more aggressive goals. The once-future state map becomes the current state map. A new future state map is drawn, with goals projected at areas that are identified as potential candidates for projects, and the process is repeated. Customer value is again improved upon and more savings are realized by the business.

A result of this process is improved customer satisfaction. This may lead to more customers requesting your services. By providing this service with less cost, for more customers, your profit increases yet again. In this way, business success is sustained. If your business is a not-for-profit, which many healthcare systems are, these savings may be passed on to the customer. This will also increase customer satisfaction.

There are many studies that evaluate the effectiveness of lean thinking within the emergency department, comparing pre-implementation data to post-implementation data. Results suggest significant improvement in time management. The purpose of this thesis is to evaluate the effectiveness of lean thinking in hospital emergency departments based on throughput time as measured by length of stay. The CMS is a source of length of stay data, provided in yearly increments. This thesis seeks to compare the length of stay metric for emergency departments which have been identified as using lean thinking to emergency departments which have not been identified as using lean thinking.

The AHA is a source for identifying emergency departments which have employed lean thinking to address length of stay data that had not met organizational objectives. Through this comparison, inferences may be determined between lean thinking emergency departments and

emergency departments which have not been identified as using lean thinking. These inferences will support or refute the hypothesis of this thesis: Emergency departments employing lean thinking will score a significantly lower median length of stay metric than emergency departments not identified as using lean thinking. The length of stay dependent variable data was extracted from the CMS Hospital Compare timely and effective care dataset.

Median length of stay data in units of minutes was assembled on a Microsoft Excel spreadsheet for each group to perform statistical analyses. To draw inferences between these two groups, three criteria need to be established: are the two groups selected dependently or independently, is the population normally distributed, and are the groups' variances homogeneous? Based on the findings of these criteria, an appropriate analytical test statistic may be selected. For the length of stay dependent variable, the sample sets were determined to have been selected independently. A lean thinking treatment group is identified through a search on the AHA website. A non-treatment group is produced by random selection from the population, none of which have been identified as employing lean thinking through the AHA website.

Descriptive statistics were produced for the entire population. Based on the descriptive statistic results, the population was reasonably considered to be non normally distributed. Based on this determination, scores were ranked in descending order. Median length of stay ranked scores were then copied into separate columns for each sample group. Each column contained seven scores and was labeled non-treatment or treatment. Ranked scores for the non-treatment group and treatment group were analyzed for homogeneity of variance utilizing Levene's test. Results suggest homogeneity of variance assumption was satisfied.

Based on these three criteria findings, the independent t-test was selected to draw inferences between these two groups. Performing a two-tailed test with a .05 level of

significance, the result of the independent t-test suggest evidence supporting the conclusion that emergency departments identified through the AHA employing lean thinking do not provide a statistically significant length of stay metric compared to emergency departments which have not been identified as using lean thinking to address length of stay metric. When comparing the mean length of stay score of non-treatment group (141) to the lean thinking group (177), lean thinking produced less optimal scores. What this implies is that employment of lean thinking in the emergency departments identified in this thesis was less effective as a quality improvement tool to address length of stay compared to emergency departments not identified as employing lean thinking.

The purpose of this thesis is to evaluate the effectiveness of lean thinking in hospital emergency departments. This thesis differs from previously published studies that have applied lean thinking in an emergency department as it compares a treatment group to a non-treatment group. Previous studies compare one emergency department pre-implementation statistics to post-implementation statistics. This thesis adds to the body of knowledge of emergency department length of stay time. It also adds to the lean thinking body of knowledge, as it compares length of stay data obtained from emergency departments identified by the AHA as employing lean thinking to address organizational objectives to data from emergency departments that were not identified by AHA as employing lean thinking.

Based on a ranked score data analysis of these two groups utilizing the independent t-test inferential statistic, length of stay means were not statistically significantly different between the non-treatment group and the treatment group. This finding presents an opportunity for the lean thinking emergency department community to explore the root causes for lack of significant throughput reduction. With this thesis, emergency departments may obtain an evaluation of

effectiveness of employing lean thinking and an idea of what investment and commitment may be required for lean thinking to lead to desired results.

A limitation of this thesis is lean thinking emergency departments were not verified to be currently employing this improvement tool to remedy length of stay time delays at the time the data was submitted to CMS. Another limitation is the non-treatment group may include other lean thinking facilities or alternative continuous improvement schemes. The non-treatment group may also include facilities that employed no improvement scheme in the emergency department to improve length of stay. A third limitation of this thesis is that inferences were made from non normally distributed data.

The design and findings of this thesis present opportunities for future research. A study may be conducted utilizing length of stay data collected from verified lean thinking emergency departments and comparing these results to other emergency departments that employ other improvement schemes, or to emergency departments that do not employ any continuous improvement initiatives. A study of this type would eliminate the uncertainty regarding validating and verifying emergency departments' use of lean thinking to address length of stay evident in this thesis. Eliminating this uncertainty would present a stronger case supporting or refuting the findings of this thesis, thereby adding to the emergency department and lean thinking bodies of knowledge.

Future research may also include a multi-year study, where the researcher obtains commitments from healthcare systems to embrace lean thinking culture. What is meant by culture is adoption of the extended value stream perspective to attainment of an ideal state. An ideal state is where businesses enter into partnerships to reduce non-value-added steps in the process, such as transportation, lead time, and sharing of space and resources through co-

location. Results obtained from these organizations may be compared to other lean thinking facilities that lack the cultural component, which may lead to potentially interesting results. If there is a significantly statistical difference in favor of lean culture, this could launch more healthcare systems to commit to change. If there is not a significantly statistical difference between full adoption of lean culture and applying lean thinking to just a few processes, this may spur further analysis, review and improvement of lean thinking concepts in a service setting.

Establishing a lean thinking culture is what Womack and other lean thinking proponents have stressed for this improvement tool to meet expectations. The first, most important step is to establish a value stream manager. This individual has responsibilities and authorities to enact a lean culture throughout the enterprise and to business partners. With this dedicated customer advocate, they may obtain buy-in from suppliers and tangential community organizations that directly and indirectly have impact on patient quality of care.

Lean culture is a perspective that is always customer first oriented, with the purpose of improving and increasing customer value as defined by the customer. This culture empowers participants to think in ways that reduce or eliminate waste to affect change, and developing partnerships are encouraged. Internal customers need to partner with other internal customers, as well as external customers, suppliers, and end users. Partnerships facilitate sharing of resources, which decreases costs in delivering value to the customer. Partnerships also offer opportunities to remove redundancies and non-value-added steps found within the product or service provision chain.

This is the ideal presented in *Seeing the whole value stream* (Jones, Womack, & Brunt, 2011, p. 51-64). In the future value stream map 1, the authors describe how material flows are mapped across all suppliers, transporters, producers and distributors, to the end user. Data

pertinent to customer value is detailed across the future value stream map, for all participants to visualize. When all participants see the map, diverse perspectives may lead to innovative solutions to commonly perceived problems. Solutions are shared amongst participants and collaboration benefits the group. This improvement in communication is realized in the future state value stream map 2. When organizations are in alignment with the same objective to provide the most value to the customer, communication is improved, which may lead to reducing demand amplification and defects that lead to overcrowding.

This communication is not meant to be one way. When partners consolidate, share resources, and have robust communication, many of the total costs associated with delivering medical care services may be significantly reduced. Total cost may be shared amongst the supply chain instead of each organization possibly spending money on the same resource. Finally, with a focus on delivering value to the customer across all organizations that have a stake in this service, changes in customer sentiment can be met without negative impact on the supply chain and the organizations that comprise the chain. These opportunities are discovered when you extend the scope of lean thinking beyond the business front and back doors.

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