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A Framework For Quantifying Sustainability Of Lean Implementation In Healthcare Organizations

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A FRAMEWORK FOR QUANTIFYING SUSTAINABILITY OF LEAN IMPLEMENTATION IN HEALTHCARE ORGANIZATIONS

by

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ABSTRACT

Due to the remarkable positive effect of lean adoption in various firms in the manufacturing sector, it has been adopted by several organizations within the healthcare industry. Although the rate of adopting lean by hospitals in the developed countries is slower than it should be, it proved to be effective in helping healthcare organizations maintain or even improve their quality of care while containing their related costs. However, such adoption did not take place until the beginning of the new millennium. And with such adoption, it has been accompanied with major challenges related to proper lean implementation, sustainability of achieved levels of performance, and staff engagement in infinite cycles of continuous improvement towards perfection. Thus, the purpose of this study is to develop a framework that helps healthcare organizations quantify their experience with lean. Such quantification is obtained by measuring the agreement level of hospital staff members about the degree of adopting two sets of critical factors of successful lean implementation within their hospital. These two sets of factors are classified as process factors and organizational factors. The proposed framework has been validated by determining the sustainability level of lean implementation within one of U.S. hospitals in the State of Florida.

The developed framework provides a balanced assessment of both process and organizational factors essential for achieving sustainable levels of lean implementation. In order to accommodate for the observed variation in lean adoption in hospitals, individual hospital

departments are considered the “analysis units” of the developed framework. In order to quantify the implementation status of lean within a hospital department, a survey-based lean sustainability assessment tool has been developed based on the defined sets of factors. The sustainability level of lean implementation of a hospital can be obtained by combining various responses of its surveyed departments. The developed framework is the first that addresses both process and organizational factors of sustainable lean implementation in a balanced manner while fulfilling the assessment needs of all healthcare organizations regardless of their current level of lean adoption. In addition, utilizing the framework within a hospital enhances employee involvement and respect for employee which are essential for sustainable lean implementation. Finally, the developed framework provides healthcare supervising authorities (i.e. ministries of health or corporate offices of hospitals’ groups) a macro-level benchmarking view regarding the progress of their hospitals towards implementing sustainable levels of lean.

To all my spiritual Fathers and Mothers

To my limitless supporting and loving parents

To my lovely wife and inspiring kids

To all family members and friends

To Saudi Arabian Cultural Mission to the United States

To Saudi Arabian Ministry of Higher Education

I dedicate this effort

Without you all

I couldn’t make it

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LIST OF ACRONYMS/ ABBREVIATIONS

Agr	The agreement measure developed by Tastle and Wierman
CSCI	Commitment to safety and continuous improvement
CUIN	Culture and involvement
Dnt	The dissension measure developed by Tastle and Wierman
LLC	Lean leadership commitment
LPM	Lean process maturity
LSAS	Lean sustainability assessment space
LSAT	Lean sustainability assessment tool
PPI	Patient pathway integration

CHAPTER 1 INTRODUCTION

1.1 Introduction and Documents Outline

Despite their variation in magnitude from one country to the other, healthcare expenditures are remarkably increasing worldwide. Once this increase goes beyond realistic levels, it will jeopardize the quality of care provided by healthcare institutes. One of the tactics that are used to put some control on hospitals' operational expenses is the implementation of effective quality improvement initiatives utilized successfully by firms in manufacturing industry. In these firms, objectives like decreasing process defects, reducing process cycle time, and increasing resource utilization have been amazingly achieved by following such quality initiatives as lean. Although the rate of adopting such initiatives by hospitals in the developed countries is slower than it should be, these initiatives proved to be effective in helping healthcare organizations maintain or even improve their quality of care while containing their related costs.

However, similar to lean adopting firms within the manufacturing sector, proper lean implementation and sustainability of the improvements obtained are among the challenges facing lean implementing healthcare organizations. This challenge has been recognized by lean adopting hospitals in such countries as the United States, Canada, and the United Kingdom, where lean started to be adopted at the beginning of 2000's. Thus, the purpose of this study is to develop a framework that helps healthcare organizations assess their implementation of lean based on critical factors found in literature for successful lean implementation. In addition, the

proposed framework has been validated by determining the sustainability level of lean implementation within one of U.S. hospitals in State of Florida.

The remaining part of this chapter presents the research problem statement in addition to the research objectives, questions, and contribution. This is followed by chapter two which provides an overview about literature review conducted. Chapter three illustrates the research methodology and data analysis techniques while chapter four presents the baseline lean assessment framework together with the lean sustainability assessment tool and framework implementation and results. Chapter five is the conclusion of this document which presents a summary of results and recommendations of the study.

1.2 Research Problem Statement

In order to contain the rapidly increasing expenses of healthcare delivery, many U.S. healthcare providers either have already implemented or seriously consider implementing the lean within their organizations. However, levels of lean implementation within these hospitals represent a wide spectrum with a common challenge of achieving higher levels of sustainability. Until January 2011, there wasn't any tool developed, specifically, to assess the sustainability of lean implementation in hospitals. Similar to most of the lean assessment tools available in the literature, the hospital-based assessment tool found mixes between system level components and specific tools utilization components when assessing levels of lean implementation. Despite this unique healthcare lean assessment tool, other tools available in the literature, most of which are geared towards assessing lean implementation in manufacturing sectors, cannot be directly

adopted by hospitals. Additionally, most of these tools evaluate the firms' experience with lean from process-based technical perspective with little considerations for cultural-based organizational perspective. Moreover, a previous research effort has identified several levels of maturity of lean implementation but without providing a quantitative-based mechanism against which organizations can assess their level of implementation. Such a mechanism is essential as a roadmap for lean implementing organizations so they recognize their current stage of implementation and develop action plans for progress accordingly.

1.3 Research Objectives

The objective of this study is to develop a framework for assessing the sustainability of lean implementation in organizations within the healthcare industry. The developed framework provides a balanced assessment of both process and organizational factors essential for achieving sustainable levels of lean implementation. Since the current level of lean implementation in hospitals varies from adopting lean within one department only to including all hospital departments, both medical and non-medical, the "analysis units" of the developed framework will be hospital departments. In order to assess the implementation status of lean across the departments in a hospital, a survey instrument has been developed based on a set of critical success factors identified from the literature. The sustainability level of lean implementation of a hospital can be obtained by combining different responses of its surveyed departments. Provided that the same group of departments has been surveyed in more than one hospital, the

sustainability level of lean implementation in these hospitals can be compared by using the developed framework.

1.4 Research Questions

- How sustainable are the efforts of a surveyed hospital with regards to implementing lean within its various departments?
- Within a surveyed **hospital department**, what is the current level of adopting the set of process factors necessary for successful lean implementation?
- Within a surveyed **hospital department**, what is the current level of adopting the set of organizational factors necessary for successful lean implementation?
- Within a surveyed **hospital**, what is the current level of adopting the set of process factors necessary for successful lean implementation?
- Within a surveyed **hospital**, what is the current level of adopting the set of organizational factors necessary for successful lean implementation?
- Provided that same group of departments has been surveyed in more than one hospital, how can the sustainability level of lean implementation in these hospitals be compared?
- For each surveyed department/ hospital, what are the actions required to advance towards more sustainable levels of lean implementation?

1.5 Research Contributions

The developed lean sustainability assessment framework is the first that addresses both process and organizational factors of sustainable lean implementation in a balanced manner. In addition, as many healthcare institutes have considered or are currently considering the adoption of lean, the developed framework is designed to fulfill the assessment needs of all healthcare organizations regardless of their current level of lean adoption. Moreover, the developed framework helps individual healthcare organizations diagnose the sustainability level of their lean implementation efforts and define those characteristics of critical success factors which are missing or less enforced. Furthermore, utilizing the framework within a hospital enhances employee involvement as well as respect for employee aspects which are essential for sustainable lean implementation. This is because all staff members of each department in the surveyed hospitals are, ideally, expected to participate in the assessment process. Finally, the developed framework provides healthcare supervising authorities (i.e. ministries of health or corporate offices of hospitals' groups) a macro-level benchmarking view regarding the progress of their hospitals towards implementing sustainable levels of lean.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

By developing and implementing what is known today as the Toyota Production System (TPS), Toyota was able to turn its 1950s near bankruptcy firm into a global company leading the automobile industry (Chalice, 2007). It has become the most efficient carmaker which produces world-class-quality cars. The decades of Toyota steady, continually succeeding performance make executives of traditional mass production-based carmakers start to benchmark their own companies with Toyota. The motive behind such benchmarking is Toyota's ability to manufacture wider variety of products at lower volumes with fewer defects while utilizing half of the human effort, manufacturing space, capital investment, and product development cycle time utilized by its mass production-based counterparts (Chalice, 2007). Toyota's solid growth, resulting from applying their system to various production activities, has attracted a wide spectrum of academic and business audience from outside the auto-industry. As a result, TPS, also known as lean system, has been adopted by many manufacturing and service organizations.

However, not all adopting organizations gained similar results as Toyota did. This is due to the fact of adopting lean tools without understanding the core concepts around which the whole system originally was built. In order to help such organizations get the best out of their experience with lean, significant efforts have been made, by researchers, to study the set of factors that lead to a sustainable level of implementing lean so that levels of performance and

cost savings similar to those witnessed in Toyota can be generated. Some of these efforts are focused on developing assessment tools by using which lean adopting firms can know how much lean they are, according to a defined set of critical success factors, while other efforts are focused on defining various levels of maturity which could be observed in a lean adopting organization. However, most of these efforts are performed and/ or geared towards lean implementation setups in the manufacturing sector while few consider both manufacturing and service sectors. Among those service sectors which started to adopt lean and attracted researchers' attention over the last decade is healthcare. Thus, this chapter covers aspects related to lean development and definition, lean assessment tools, lean maturity stages, and lean applications in healthcare. Although the literature has different definitions for lean and Toyota Production System, which is also known as Toyota Lean Production System, these terms will be used interchangeably throughout the document to refer to the broader meaning that combine them all which is simply "doing more with less."

2.2 Lean Concept

The concept of lean has been developed in the automobile manufacturing field and got spread within and outside that segment of global industry. Toyota is the pioneer company at which this concept has been developed. Thus, it is known as Toyota Production System (TPS). As a response to technological, financial, and labor challenges which Toyota was encountering in 1950s, it was able, over three decades, to develop a new concept for producing automobiles

that superseded production systems used at that time, in both yield and quality, while consuming fewer resources and reducing manufacturing lead times (Dennis, 2002).

It is greatly interesting to notice that most of lean tools and concepts were developed much earlier than 1950's (*Lean enterprise institute.*2009; Dennis, 2002; Womack, Jones, & Roos, 1990). However, it was Ohno's wisdom and other Toyota members which had put the several pieces of the lean system puzzle into their correct places and developed this effective production system (Womack et al., 1990). The response of Mr. Ohno to a question about "what Toyota is doing now?" lays down the foundation of the whole system. His answer simply was "all we are doing is looking at the time line from the moment the customer gives us an order to the point when we collect cash. And we are reducing that time line by reducing the non-value-added wastes." (Ohno, 1988; p. ix) By doing so while enforcing the "respect for humanity" concept at all levels of the organization, Toyota was brilliantly able to create a teamwork-based organization with a primary focus on continuous improvement (Dennis, 2002; Ohno, 1988). Although TPS concepts and tools led to remarkable process improvements within and outside the automobile industry, other quality improvement tools and methodologies can be incorporated to achieve lean primary objective, stated above in Ohno's answer, as long as this objective remains to be the primary focus of the adopting organization (*Lean enterprise institute.*2009).

Led by Toyota, lean producers are able to produce volumes of variety products, triggered by customer desires, while avoiding the high cost of craft production and the rigidity of mass production (Womack et al., 1990). Such level of performance is achieved by using highly flexible, increasingly automated machines and forming teams of multi-skilled workers to operate at all levels of the organization (Womack et al., 1990). The major characteristic that

distinguishes lean producers from mass producers is setting their objectives at perfection and that is translated into endless improvement cycles aiming at continuous cost reduction, zero inventories, and zero defects while providing product variety with high levels of quality (Womack et al., 1990).

2.2.1 Definition of Lean

As it took Ohno thirty years to reach a mature stage of the system he developed to improve the overall efficiency and enhance the work environment at Toyota, it can be easily realized that TPS or lean production is a *do*, a path towards perfection driven with one simple question: what is the need? Due to the fact of having more than one correct answer, there would be more than one path to meet the defined need (Dennis, 2002). Thus, a precise definition of lean system may not exist (Dennis, 2002; Ohno, 1988). However, several lean definitions are available literature. See for instance (Shingo & Dillon, 1981), (Dennis, 2002), (Detty & Yingling, 2000), (Chalice, 2007), (Rooney & Rooney, 2005), and (Alukal & Chalice, 2007). All definitions stated in these references are common in describing lean as a way of using all available resources (i.e. man, machine, material, space, and time) in their minimum possible levels to satisfactorily fulfill customer defined needs; with the objective of decreasing these levels while pursuing perfection through continuous improvement. The definition of (Chalice, 2007) of Toyota lean Production as "an improvement philosophy or framework that is implemented around a problem-solving methodology" p.70 gives the adopting organizations the freedom in selecting the framework and the methodology which suit them the most. However,

"what's most important is not the particular improvement philosophy and problem-solving methodology selected but rather the simple containment of the organization to demonstrably pursue continuous cost and quality-improvement as part of its ongoing mission and value." (Chalice, 2007; p. 70)

2.2.2 House of Lean

Due to the difficulty that has been proven about grasping the lean system as a whole, many lean applications, outside Toyota, tend to be for some of the activities only and that is the reason behind the failure witnessed in achieving the expected results of improvement. In order to gain maximum benefits from lean implementation, it is important to know the main principles on which this system is built in addition to understanding the relationship between different lean activities and these principles. Figure 1 illustrates the house of lean production system with activities related to its major principles (Dennis, 2002). In this house, stability and standardization are the foundation, just-in-time (JIT) and jidoka, or autonomation, are the walls or pillars, involvement is the heart, and customer focus, which is the goal of the system, is the roof. The secret behind Toyota success with lean resides in the continuous reinforcement of system's core principles while understanding the interconnection relationship among their various activities. While a detailed description of lean principles and tools can be found in (Dennis, 2002), (Alukal & Chalice, 2007), (Womack & Jones, 1996), and (Rooney & Rooney, 2005), a demonstration about how these principles and tools are relating to and interacting with each other is presented below.

Starting from the roof of the house, customer focus is basically built around providing customers with high quality products while reducing cost and production cycle times through continuous elimination of muda or waste. However, due to broader expectations of today's customers, such objectives as safety, environment, and morale need to be added to the core goal of lean companies. Thus, core goal of lean companies should fulfill these customer objectives by continuous elimination of waste (Dennis, 2002). In addition, there must be a daily check that confirms the alignment of the conducted production activities with the advancement of these objectives. Otherwise, it is pure muda or waste.

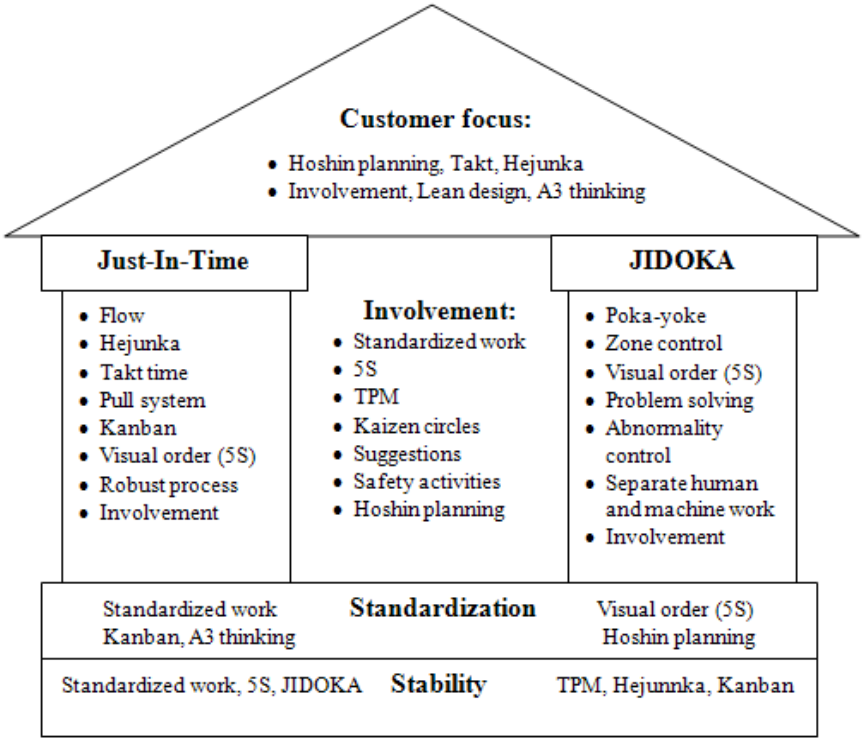


Figure 2.1 Lean activities (Dennis, 2002)

Muda is a Japanese word of waste. It is defined as any non-value added activity which the customer is not willing to pay for and can be stopped without affecting the produced products (Dennis, 2002). There is a 5/95 value added to muda ratio in most of production daily operations where this muda has eight different types (Dennis, 2002). Having these types of waste identified and eliminated represent a huge opportunity for improvement while enhancing customer objectives fulfillment process. The eight types of muda or waste are:

- **Motion:** any unnecessary human or machine motion that affect productivity and/or safety due to poor ergonomic designs, poor equipment related layout, or poor environmental conditions (Dennis, 2002).
- **Delay (Waiting):** any waiting for process, worker, material, or equipment so that next step in the production can be started. As the lead time, the time between receiving customer order and delivering the desired product, is the summation of processing time and retention time, reducing unnecessary delays will reduce retention time, which usually exceeds the processing time, and that will get the product or service outcomes faster to customers' hands (Dennis, 2002; Rooney & Rooney, 2005).
- **Conveyance (Transportation):** any waste related to excess material movement around the production area. They could be resulting from poor workplace layout, traditional patch production process, or the equipment size. Although conveyance is a necessary form of muda due to the need of moving materials in conducting manufacturing and service processes, it must be minimized (Dennis, 2002).

- **Correction (Defects & Rework):** any activities related to making and repairing defects. Such resources as material, time, and energy could be consumed in these activities and that will impact the overall productivity of the related processes (Dennis, 2002).
- **Overprocessing:** this kind of waste could be either in the form of producing more than the requirements of the customer or due to poor tool or product design (Dennis, 2002; Rooney & Rooney, 2005).
- **Inventory:** any inventory level more than the absolute minimum of raw materials, parts, and work in process (WIP) necessary for one-piece flow of production (Dennis, 2002; Rooney & Rooney, 2005).
- **Overproduction:** since it is the root for almost all other type of waste, major achievements towards lean objectives could be made when this kind of waste is eliminated. Overproduction could mean any or all of the following: engaging workers with doing things not yet ordered (motion), producing in large batches (waiting), moving finished goods unnecessarily (conveyance), making or repairing defective products found in large batches (correction), and carrying raw materials, parts, and WIP more than necessary (inventory) (Dennis, 2002).
- **Knowledge Disconnection (Poor Staff Utilization):** this kind of waste could exist within any organization, horizontally or vertically, or between the organization and its suppliers and customers. Negative effects like frustration and missing opportunity as well as inhibiting the flow of ideas and creativity could be resulting from knowledge disconnect, which mostly stems from poor staff utilization (Dennis, 2002; Rooney & Rooney, 2005).

Although it is important to learn how to see waste, the lean system has another important objective – creating continuous flow; based on customer pull rather than push mechanism. In order to achieve this objective, stability must be established first (Dennis, 2002). Stability in the 4 Ms (man, machine, material, and method) is essential to make significant improvement (Dennis, 2002). Activities like visual management and 5S are used at the beginning of the stabilizing process since they help developing method and machine stability by supporting standardized work and total productive maintenance (TPM) activities (Dennis, 2002). In addition, 5S helps stabilizing man and material involved in the production process by providing point-of-use information required for just-in-time (JIT) production and that simplifies the process of decision making. However, in process stabilizing stages, such non-lean actions like increasing buffers or adding resources, man or machine, could be temporally allowed to meet internal and external customers' obligations until the cause of an encountered problem is identified and resolved.

Once stability has been achieved, work should be performed in a standardized manner. In lean system, thick volumes on shelves do not represent standards. They are, instead, simple, clear images that visually illustrate desired conditions (Dennis, 2002). By standardizing work, out-of-standard conditions can be instantly spotted in order to be corrected quickly. In addition, on the way towards perfection, standards on which process tasks are performed change constantly because of the muda that exist, even in the best processes that are performed (Dennis, 2002). Thus, in lean system, work standards are constantly changed based on team members input so that processes would be improved continuously. Improving efficiency through manpower reduction and increasing value added activities in each process is the main objective of work

standardization which could be achieved through conducting several rapid continuous improvement events (kaizens) attacking cycle time, layout, and work sequence of processes so that a production/ service flow could be developed (Dennis, 2002).

Now that production processes are stabilized and standardized, just-in-time (JIT) production can be made through better sensing the takt time and abnormality control. JIT is a continuous flow of production where customers can pull, based on defined values, what they want while satisfying their type, quantity, time, and location constraints (Dennis, 2002). Tools like kanban, 5S, production leveling (heijunka), value stream mapping in addition to worker involvement are utilized to achieve JIT production. In order to achieve the target of zero defects at lean processes, jidoka concept is applied by continually involving team members in 100 percent inspections and error-proofing (poka-yoke) related tasks that strengthen process capability, defects-zone containment, and feedback activities (Dennis, 2002).

As seen from the above, team members are involved in all lean activities. Such techniques as kaizen circles and suggestion program are utilized to encourage team members' involvement in a fair hassle-free environment supported by supervisors and managers at all levels of the organization (Dennis, 2002).

In order to assure the alignment of all lean production activities carried out within all lean principles comprising the lean house, hoshin planning is utilized. Techniques like Plan-Do-Check-Act (PDCA), catchball, nemawashi, A3 thinking, and the control department concept are exercised throughout hoshin planning phases to translate organizational strategies and tactics into meaningful actions which cascade at all levels of the organization (Dennis, 2002). Thus, hoshin planning closes the loop of the lean system, which starts by defining customer needs, through

assuring that these needs have been properly addressed and achieved. It also assures the progress toward perfection while achieving customer objectives through continuous improvement efforts that eliminate waste, improve quality, and reduce cost and lead time (Dennis, 2002).

2.2.3 Lean Implementation Framework

One of the widely known frameworks for implementing lean comprises five steps. The framework could be applied by any organization in order to move towards perfection by improving quality and eliminating waste in a systemic approach. The steps of this framework are (Womack & Jones, 1996):

1. Identifying value: value should be determined as per the end customer of each type of product made or service provided by the organization.
2. Mapping the value stream: all steps (both value adding and non-value adding) involved in good production or service offering which comprise the related value stream should be identified so that the non-value adding steps can be eliminated whenever possible.
3. Creating continuous flow: products or services should flow smoothly toward the customer by arranging the value adding steps involved in a tight sequential manner.
4. Establishing pull system: make customers of downstream steps pull value from upstream steps of the created flow in order to synchronize the pace of production/ service delivery with the rate of customer demand.

5. Seeking Perfection: repeat the previous steps to continuously eliminate the waste identified in the value stream as a result of the current improvement cycle so that new goals for future improvement cycles toward perfection would be recognized.

However, this journey of lean transformation should have a starting point. Alukal and Chalice (2007) suggest initiating the start of such journey by one or more of the activities listed below:

- Value stream mapping organizational processes to identify and eliminate non-value added activities.
- Conducting lean baseline assessment, through interviews, process observations, analysis of reliable data, and/ or informal flowcharting, will help identifying gaps from which the lean improvement plan could start.
- Mass training employees in lean, through various teach-do cycles, followed by immediate lean implementation.
- Implementing lean basic building blocks. These blocks include visual control, 5S, standardized work, point of use storage (POUS), and streamlined layout.
- Conducting a pilot rapid improvement project, Kaizen event, on a chosen bottleneck or constraint area in order to achieve breakthrough lean improvement.
- Initiating an organization wide change management that ensures aligning organization's strategies and employee goals followed by changing the traditional processes' push culture to lean pull.
- Developing a Pareto chart to analyze the overall equipment effectiveness (OEE) which may spot the biggest opportunities from which the lean journey should start.

Nonetheless, successful lean transformation is highly dependent on crucial organizational characteristics that form a healthy culture of lean environment. Some of these characteristics include respect for employees through everyone's involvement in the improvement process, limitless executive leadership commitment to pursue perfection, team-based continuous improvement activities, and good cultural change management during lean transformation (Alukal & Chalice, 2007; Dennis, 2002). And most importantly, developing the right thinking way to identify the need and put the right countermeasure or solution to fulfill that need accordingly (Dennis, 2002). These characteristics, which are considered as essential prerequisites for sustainable lean implementation, are more illustrated in the following sub-section.

2.2.4 Lean Implementation Prerequisites

Lean culture stems from considering the lean production as a *do* or path towards perfection. Such consideration develops the intensity required to encourage effective teamwork and active team members involvement through sharing common understanding, provided by visual management techniques, towards answering the question of "How can we do things better?" in a scientific-based setup by using PDCA cycle as a core management model for the whole organization (Dennis, 2002). However, in order to assure achieving remarkable outcomes, an equal team member's involvement and respect must be encouraged (Dennis, 2002). Thus, it is hard, though achievable, to embrace lean principles completely unless implementing organizations develop a set of characteristics necessary for successful lean implementation (Dennis, 2002).

Understanding Toyota's success while implementing its lean system can be much easier if the paradox behind the observed success is realized. Spear and Bowen (1999) state that the main reason behind this giant automaker creativity and flexibility is the rigid specification of everything performed at each manufacturing process. By having built-in mechanisms to signal problems automatically and responding to the revealed problems continuously, Toyota's seemingly rigid lean manufacturing system gained its flexibility and adaptability to changing circumstances (Spear & Bowen, 1999).

Thus, in order to build the best lean structure around the basic essential question which defines the customer's need, lean implementing organizations should have the following (Alukal & Chalice, 2007; Dennis, 2002; Shingo & Dillon, 1981):

- Organizations should work according to the new economics, known as the minus-cost principle: in this principle, the profit is determined by the market since its calculated based on the following formula:

  Price – Cost = Profit

  instead of:

  Cost + Profit = Price

  Adopting the minus-cost principle helps the organization strive for cost reduction, thorough eliminating waste, in order to gain decent profits especially with the constant or even declining selling prices most of today's industries are facing.
- All employees must be respected and their skills must be equally developed based on the needs defined by end value delivered to customers.

- Executive leadership must develop a commitment for continuous improvement toward perfection.
- An empathetic Change Management must be exercised prior and during lean implementation where improvement efforts are conducted while considering "the warm heart principle: hard on problem, easy on the people." (Dennis, 2002; p. 139)
- Organizations should adopt scientific-based problem solving methodologies inspired with the question of "How can we do this better?"
- Organizations should encourage team-based improvement activities which are based on team members' creativity prior to jumping to capital investment solutions.
- Solutions developed by team members should be implemented as soon as possible as long they are useful even if they are sub-optimal solutions.
- Systems and systems thinking: organizations should prioritize lean activities based on their impact in achieving stated organizational objectives through understanding the relationship between those conducted activities and the achievement of stated objectives.
- Developing the right "thinking way": lean is a transformation journey towards perfection driven by the need with more than one correct answer. Self-awareness and endless practice are the only ways to find which answer is more effective. This "thinking way" is highly emphasized by lean sensei since it is believed that it can be taught like many other skills. All members in lean organizations should be

equipped with this concept prior to start the transformation journey. The answer a Toyota executive gave when he was asked about the PDCA cycle shows how long this journey could be. His response was “Ah. PDCS. It took me ten years to learn plan, ten years to learn do, and ten years each for check and act. Now I begin to understand PDCA.” (Dennis, 2002; p. 17)

2.3 Lean Application in Hospitals

Worldwide, healthcare systems are suffering a rapid cost increase with considerable decline in quality of the offered care. For instance, health insurance costs in the U.S. have an average annual increase of 11 percent between 2002 and 2006 (Chalice, 2007). As part of this increase in health insurance premiums is due to introducing new advanced technologies and the aging population, a considerable part of it is doubted to be caused by running inefficient and ineffective processes within the current setups of healthcare providers. For instance, the total waste produced by healthcare providers in both non-patient care and patient care operations is assumed to be between 30 – 40 % of their total cost (Chalice, 2007). Improving efficiency and effectiveness of these processes represent an opportunity for containing healthcare costs while improving the quality level of care delivered and enhancing both patients and staff satisfaction (Chalice, 2007; Miller, 2007). As implementing lean principles has a validated impact on improving the performance of several industries, these principles are expected to improve the quality of the provided healthcare services and reduce costs through a continuous waste

elimination process (i.e. leading to higher levels of performance while pursing perfection) (Chalice, 2007).

Part of their efforts to improve the quality of care provided by their organizations, some healthcare institutes have adopted Total Quality Management (TQM) and/or Continuous Quality Improvement (CQI) initiatives. However, within the healthcare industry, both initiatives did not remarkably succeed since they were not completely understood (Chalice, 2007). As a result, they were occasionally applied in order to satisfy such inspection requirements as those of the Joint Commission (TJC) and not to achieve high quality and low cost levels of the offered healthcare services (Chalice, 2007).

Although lean is similar to TQM, in assigning quality monitoring and improvement tasks to all organization members in continuous basis, as well as to CQI initiatives, in constantly performing customer focused process analysis and measurement to gain improvement, it gets distinguished among them by having the management-supported focus in cost, as related to values defined by the customer, while involving all organization members, regardless of position, in quality improvement efforts conducted through team-based activities (Alukal & Chalice, 2007; Chalice, 2007). Thus, lean would help "construct a hospital model that is simply centered on the patient, his or her physicians, nurses, and critical ancillary functions and that model contains little or no excess overheads" (Chalice, 2007; p. 40). However, creating an environment that reserves and advances respect for employees is the most critical success factor for lean implementation (Chalice, 2007).

As inferred from the conducted literature review, there are many successful cases of lean implementation in the healthcare area, in addition to the availability of reasonable material that

covers lean transformation frameworks designed to suite the environment of healthcare organizations. See for instance (Alukal & Chalice, 2007), (Caton-Hughes & Bradt, 2007), (Fine, Golden, Hannam, & Morra, 2009), (Jones, Mitchell, & UK, 2006) (Joosten, Bongers, & Janssen, 2009), (Thompson, Wolf, & Spear, 2003), (Zidel, 2006), and (Leone & Rahn, 2010). Yet, having healthcare institutes that implement the whole concept of lean aiming to achieve a world-class level of quality improvement and cost reduction is still rare. The remaining part of this section includes an illustration of literature reviewed about applications of lean concepts and tools in healthcare institutes.

2.3.1 Frameworks for Implementing Lean in Hospitals

Based on Toyota lean production methods, Robert Chalice has developed 46 steps to show how lean methods could be applied to healthcare (Chalice, 2007). These steps start with defining healthcare values from a patient perspective and end with taking a total view of the healthcare system to identify available opportunities for quality and cost improvements. Chalice suggests that healthcare providers set up a three – five years strategic plan to implement the steps he has developed.

As an essential foundation for lean successful implementation in healthcare, Chalice states the importance of "respect for employees" concept, which is based on such principles as all opinions are respected, all employees are encouraged to perform tasks that improve their jobs and their organizations, and organizations must take any necessary actions to retain good employees. In addition to this important concept, Chalice suggested steps for improving

healthcare system and emphasized the importance of making continuous cost reduction and quality improvement as part of the daily activities of the organization. This could be obtained by embedding organizational structures for such activities through building small work teams led by a supervisor and supported by a group leader from the top management of the organization.

Another effort in providing healthcare organizations with a lean-based improvement methodology is the one suggested by (Alukal & Chalice, 2007). They develop lean healthcare building blocks by which healthcare organizations can build, sustain, and improve their lean system in an effective and efficient way. As Alukal and Chalice stress the importance of organizations' focus on providing true value to the patient when using the provided tools and techniques to design their processes, they consider the following blocks as essential foundations without any of which the developed lean structure will collapse or become ineffective:

- Respect for employees
- Executive leadership
- Continuous improvement teams – Kaizen events
- Empathetic Change Management

2.3.2 Implementing Lean as a Strategy for the Whole Hospital

Literature of lean implementation in healthcare includes two successful examples of applying this effective system as the operational strategy of the whole organization: Virginia Mason Medical Center (VMMC) in Seattle and ThedaCare, Inc. in Wisconsin. Based on TPS, both VMMC and ThedaCare developed their own patient-centered lean systems with specific

business focus and more accountability and that impacted, positively, their cost and quality (Miller, 2007). With the vision of being quality leaders in healthcare, the lean system of both healthcare institutes was developed. To ensure sharing this vision with the whole organization, both institutes used pictorial-based vision format to which leaders usually refer during various hospitals' events. By developing a shared vision within their organizations, both institutes laid down an essential foundation of the change management necessary in organizational culture to effectively pass through the transition stage from traditional to lean organizational setup. This foundation is the strong infinite leadership commitment to pursue perfection through continuous cycles of waste elimination and process improvement.

In order to develop their lean systems, both VMMC and ThedaCare have sent their executives to lean-operating institutes to see how the system works and gain the ability of forming an integrated lean system while considering the value stream mapping as its major component. Upon the development of their systems, both institutes ensured the involvement of their staff members by mandating the attendance of lean basic training sessions and encouraging participation in rapid process improvement workshops, or Kaizen events.

After two years of implementing lean and through conducting 175 Kaizen workshops, VMMC have recognized improvement in inventory and productivity levels, floor space utilization, lead time and setup time saving, and people and product distance travel reduction. Moreover, their process redesigning efforts resulted in significant capital investment cost savings, between $8 - $10 million, and showed decreasing trends in staffing after a continual increase in the number of full-time equivalents (FTEs) for six years. In addition to these financial

and efficiency gains, VMMC, through standardized work procedures, was able to advance clinical improvements.

Similar to VMMC, ThedaCare lean efforts led to $27 million savings while improving the quality of care, treating more patients, and retaining its large number of workers (Miller, 2007). The improved quality of care provided by this institute was reflected as a 20 – 30 % reduction in procedures' payment while providing better quality of care, a reduction in the emergency room patient waiting time, a lower mortality rates, a reduction in average length of stay, and an average of 37 minutes, far exceeding the 90 minutes national target, "door to balloon" time for patients suffering from chest pain (*Health value leaders network* 2009; *What is ThedaCare?- fox news website* 2009; Miller, 2007).

2.3.3 Implementing Lean in Hospital Departments

In addition to the previously presented cases of lean implementation as an operational strategy of the whole hospital, literature about lean in hospitals has a considerable amount of cases where lean was adopted individually by some departments within hospitals. For instance, lean was adopted to improve processes of emergency departments (Woodward, G., Godt, L., Girard, M., Fischer, K., Feeley, S., Dunphy, M., & Bouché, B., 2007), surgical units (Grunden, 2007), anatomic pathology labs (Condel, J., Sharbaugh, D., & Raab, S., 2007), and operating rooms (Leone & Rahn, 2010).

These lean-based rewarding efforts reported in literature applied lean techniques like, value stream mapping (Condel et *al*., 2007), redesigning workplace layout (Condel et *al*., 2007;

Woodward et *al*., 2007), adopting a pull system for resource dispatching based on patient condition (Woodward et *al*., 2007), creating patient or a single-piece continuous flow (Condel et *al*., 2007; Woodward et *al*., 2007), conducting rapid process improvement workshops (Woodward et *al*., 2007), 5S (Condel et *al*., 2007; Grunden, 2007), visual management (Condel, et *al*., 2007), kanban system (Condel et *al*., 2007), and poka-yoke (Condel et *al*., 2007).

Recognized benefits of conducted lean initiatives in various hospital departments included reduction in patient length of stay (Woodward et *al*., 2007), improving both patient and staff satisfaction (Woodward et *al*., 2007), better utilization of storage rooms (Grunden, 2007), freeing up rarely used equipment to be used in other areas in hospital (Grunden, 2007), overstock inventory levels reduction, and supply order time reduction (Condel et *al*., 2007).

2.4 Lean Assessment Tools and Sustainability

There are many assessment tools, developed by researchers, to help lean implementing organizations assess their experience with adopting various lean practices and tool. For instance, (Panizzolo, 1998) developed a survey to assess the level of implementing 48 lean practices applied in six areas of intervention within 27 Italian manufacturing firms from different industrial sectors. After reviewing the literature, Panizzolo developed his survey based on conceptualizing lean production as a set of best practices used in different areas of the firm. "These areas are: process and equipment, manufacturing planning and control, human resources, product design, supplier relationships, and customer relationships" (Panizzolo, 1998, p. 227).

Data of this study was collected using face-face structured interviews to fill the five-point Likert scale questions of the developed survey. Level of implementing lean in surveyed organizations was determined based on responses collected from firms' members holding managerial positions within the analyzed companies.

Another lean assessment tool available in literature is the Lean Enterprise Self Assessment Tool (LEAST) Developed at MIT under the Lean Aerospace Initiative (LAI) (Nightingale and Mize, 2002). Tool's utility was extensively field-tested in more than 20 firms located between the United States and the United Kingdom. The LEAST has been developed to assess the firms' maturity in using lean principles and practices. The developed roadmap using this tool is associated with issues related to firm's strategy, structure, and internal and external relations among key stakeholders during the transformation phase. In addition, the tool consists of a set of nested feedback loops that refines the future strategic objectives of lean adopting firms in order to improve utilization of resources that are freed as a result of conducted continuous improvement initiatives (Jørgensen, Matthiesen, Nielsen, & Johansen, 2007; Nightingale & Mize, 2002). Firms' management (i.e. the senior leadership team) conducts this self assessment to measure the progress of firm's capability in meeting stated lean visions on a continual basis. Based on 54 lean practices expressed in the enterprise level and distributed over three main sections, managers determine, using this tool, the current and desired leanness level of the firm on enterprise level.

An integrated lean assessment check-list has been developed by Sánchez and Pérez (2001) in order to be used by manufacturing firms to assess changes towards lean production. The assessment check list has been developed based on defining the lean productions as "a

conceptual framework based on a few established principles and techniques." p.1434. It also assumes an integrated, rather than gradual, approach in regards to implementing lean elements within the manufacturing firms. All indicators of this tool are related to the manufacturing area since activities of this area should be optimized prior to any other areas in the manufacturing firms. This assessment tool consists of 36 indicators categorized into six groups identified from literature and have been tested on a group of manufacturing firms through mailed surveys filled by firms' operation managers. The groups categorizing the indicators of this assessment tool are multifunctional teams, elimination of zero-value activities, production and delivery JIT, continuous improvement, supplier integration, and flexible information system.

Goodson (2002) has developed his Rapid Plant Assessment (RPA) tool to evaluate the improvement opportunities in both facilities and processes of manufacturing firms. It is composed of an 11 categories rating sheet, to assess the leanness of a plant, and a questionnaire of 20 yes-or-no questions, to assess the plant utilization of best practices in regards to the categories stated in the rating sheet.

Categories included in this tool are:

- customer satisfaction,
- safety, environment, cleanness, and order,
- visual management system,
- scheduling system,
- use of space, movement of materials, and product line flow,
- levels of inventory and WIP,
- teamwork and motivation,

- condition and maintenance of equipment and tools,
- management of complexity and variability,
- Supply chain integration, and
- commitment to quality.

Although the tool is designed to be used to assess plants of manufacturing firms, Goodson claims that it can be used in other organizational setups too. The RPA is a team-based tool where a group of four to five people, with lean background and diversified knowledge about the assessed plant equipment and operation processes, takes a tour in the plant and collect visual evidences, while talking to the tour guide (e.g. plant manager), about whether or not best practices are followed when conducting various processes of production. Prior to starting the tour, each group member is assigned a set of the 11 categories of the RPA tool and they should conduct some research to get a general background about practical and regularity requirements of the plant they are going to assess. Right after the tour is completed, group members meet and share and document their observations.

Soriano-Meier & Forrester (2002) developed a self-administered survey tool to assess manufacturing firms' commitment to lean production and identify their level of lean principles adoption. His study was conducted on 30 tableware firms in the UK ceramics industry to find out if lean is applicable to craft production sector. Two questionnaires were developed to analyze the selected firms by addressing the questionnaires to two firm’s different management levels (operational managers and top management) to find out the level of adopting lean production principles in addition to measuring the commitment level of management to lean production. The

tool was developed based on the definition of leanness stated by (Karlsson & Åhlström, 1996) and (Boyer, 1998).

Based on literature review conducted to identify practices of lean manufacturing in addition to exploring the existing lean assessment tools, Doolen & Hacker (2005) developed a survey instrument to assess lean implementation within organizations by finding out the level of implementing a range of lean practices within electronic manufacturers. A variation noticed in regards to the level of implementation of lean practices included in the survey due to operational, organizational, and economic factors. Lean practices included in the survey instrument were categorized into six impact areas:

- Manufacturing equipment and processes,
- Shop-Floor Management,
- New Product Development,
- Suppliers Relationships,
- Customer Relationships, and
- Workforce Management.

Another survey- based assessment tool was developed by Srinivasaraghavan and Allada (2006) to measure, quantitatively, the leanness of a production firm through benchmarking it against leaner firms. The survey was developed based on LEAST and lean characteristics. The tool was developed to help lean adopting firms measure the achievement they made so far in their lean journey.

As compared to the number of lean assessment tools which have been developed in various manufacturing sectors, the availability of such tools to be utilized by healthcare

organizations is relatively rare. One of these assessment tools is called “Lean Assessment for Hospitals” which has been developed by Leonardo Group Americas (2011). The tool is made of 80 (Agree/Disagree) questions under 16 different categories. These categories are:

- Staff communication,
- Visual hospital and organization,
- Staff cross-training and flexibility,
- Mistake proofing,
- Quick changeover,
- Quality systems,
- Supply chain management,
- Patient flow,
- Total productive maintenance,
- Pull systems,
- Standard work,
- Finance and accounting,
- Performance measurement,
- Patient communication, and
- Lean management system.

Using this tool, a group of hospital staff is expected to set together and answer all the questions in order to get a score out of 100 for each category. After that, the resulting scores are plotted in a radar chart format and an action plan is developed accordingly. Although the tool is designed

to conduct lean assessment in hospital level, it is also promoted as a tool for assessing lean in department level. This is done by skipping those questions which do not apply to the assessed department(s).

The lean assessment tools illustrated above have been developed with the aim of identifying the level of adopting this system within lean organizations. Most of these tools are designed to be used within specific industry. Since lean is originated in the manufacturing industry, no wonder that most of these assessment tools are developed and geared to be used within this industry. However, due to the complex nature of lean resulting from the huge amount of interconnectivity among its concepts and various tools, the developers of these assessment tools try to base them on a conceptualizing model that justifies categorizing number of lean practices under a set of organizational functional areas (Jørgensen et al., 2007; Panizzolo, 1998). By analyzing these assessment tools, it appears to be a common practice that both lean practices and functional areas are defined from literature and merged together according to the developed conceptualizing model. A variation has been observed in model conceptualization, which can obviously be linked to the various definitions of what lean is composed of.

As the set of constructs that define lean production has changed over the last two decades (Jørgensen et al., 2007), lean assessment tools are expected to follow the norm too. After reviewing a set of lean assessment tools available in literature, (Jørgensen et al., 2007) concluded that the good assessment tool should reflect the complex nature of lean in an accurate way. Thus, such a tool should consider the two sets of variables which define the evolved nature of lean. These two sets represent, simultaneously, the variables of lean from a technical perspective, lean tools and practices, and an organizational perspective, lean culture development. Such

characteristic is missing in many of the assessment tools available today (Jørgensen et al., 2007). As a result, (Jørgensen et al., 2007) developed a lean capability model to help organizations assess their progress towards sustainable levels of lean implementation according to five different maturity levels. These levels are:

- Sporadic production optimization,
- Basic lean understanding and implementation,
- Strategic lean interventions,
- Proactive lean culture, and
- lean in the extended manufacturing enterprise (EME)

Although this maturity model just states both technical and organizational characteristics which organizations will have while being at any of the defined maturity stages, it does not provide an assessment mechanism by which an organization can identify its current level on the defined stages.

2.5 Issues of Lean Sustainability in Healthcare Organizations

The ability of sustaining the achieved levels of improvement is a common concern addressed by many researchers investigating lean implementing healthcare organizations in the United State, the United Kingdom, and Canada. The Canadian Literature about this concern identified strategy & alignment, leadership, and behavior & engagement as the critical factors organizations should embrace to secure sustainability of the achieved results (Fine et al., 2009). A study about the National Health Services (NHS) experience with lean implementation in UK

addressed the gap between sustainability and practical lean application (Caton-Hughes & Bradt, 2007). The study suggested that leadership, communications, and workforce engagement are essential elements for lean successful implementation.

The U.S. literature states that respect for employees, executive leadership, continuous improvement teams, and empathetic change management are the foundations for a sustainable lean adopted system within healthcare industry (Alukal & Chalice, (2007). Another view in the U.S. literature about what develops a sustaining lean organization is adopting a nested organizational structure which supports employee involvement and learning (Chalice, 2007; Spear, 2005). This is achieved through encouraging front line staff to improve their processes, using scientific-based methodology, in a fair hassle-free environment supported by supervisors and managers at all levels of the organization. However, this requires high level of executive support, setting the organizational mindset about lean as a journey, not an initiative, to change the way of doing business and creating team-based environment.

2.6 Literature Review Summary

Understanding the relationship between lean concepts and various lean activities and tools is essential for sustainable lean implementation. In addition, it leads to remarkable levels of performance improvement and cost reduction. Many researchers spent considerable efforts to help lean adopting organizations gain the best out of their experience, by providing means for assessing lean implementation within their organizations. Due to the complexity of lean, the assessment tools are usually developed based on a model that conceptualizes lean main concepts

and their related practices. However, the developed assessment tools do not usually assess both technical perspectives and organizational perspectives in a balanced way.

As lean started to be implemented in healthcare organizations, there is a need for assessment tools that help the implementing organizations measure the progress they do towards sustainable lean implementation. An effort has been made by Leonardo Group Americas to provide healthcare organizations with an assessment tool that defines their current lean implementing stage and develop a roadmap to achieve better future stages. However, the tool does not address both lean perspectives in a balanced way.

Based on the literature review conducted, critical success factors for sustainable lean implementation in healthcare can be classified into two main categories each of which contains a set of related factors. These main categories together with their sub-categories are:

- **Technical Perspective**
    - Process stability
    - Process standardization
    - Patient flow streamlining
    - Mistake proofing
    - Continuous improvement
- **Organizational Perspective**
    - Leadership commitment
    - Culture and involvement
    - Respect for employees
    - Change management

CHAPTER 3 METHODOLOGY

3.1 Research Design

This study is designed to develop a framework for assessing the sustainability of lean implementation in healthcare organizations. Based on those remarks which have concluded the literature review chapter and in order to develop and validate the framework, the following steps have been executed:

- Identifying critical success factors for sustainable lean implementation,
- Categorizing identified factors into two main groups: process factors and organizational factors,
- Within each group of factors, assessing the necessity of combining more than one factor together in order to develop a survey instrument, (i.e. the lean sustainability assessment tool (LSAT)) that suites healthcare organizations,
- Developing survey questions for the defined components of LSAT,
- Validating the content of the assessment tool,
- Determining data analysis technique which complies the goal of the study,
- Illustrating the appropriateness of the selected data analysis technique for the objective of the study through analyzing simulated data of a group of nine hospitals, and

- Assessing the reliability of the developed lean sustainability assessment tool and validating the usability of the developed lean sustainability assessment framework by administering the developed survey in one of U.S. hospitals in State of Florida.

3.2 Questionnaire Design

Scaling is one of the common methods of combining a number of related measures to represent one underlying concept (De Vaus, 2002). Data reduction and complexity of the measured concept are usually the motive for developing such scales (De Vaus, 2002). Using sets of variables without scaling is challenged with the overwhelming interpreted details resulting from the analysis of each measure of the concept individually and the production of conflicting uninterruptable results due to using conflicting set of measures of the explored concept (De Vaus, 2002). A more rounded overall measure can be obtained by combining a set of measures each of which taps an aspect of the underlying concept (De Vaus, 2002). However, this solution has its own challenges too. Whether or not the combined set of variables actually measure the same underlying concept, and criteria which determine the method of developing such composite measures are among the important issues which must be considered when scaling (De Vaus, 2002). Issues that need to be considered when selecting the method for developing a scale include (De Vaus, 2002):

- Understanding the difference between unidimensional and multidimensional scales: when compared with unidimensional scales, which include a set of separate measures each of which measure one dimension of the underlying concept so that respondents

are located on a single continuum of each scale separately, multidimensional scales are considered as more complex and provide more rounded measurement system which locate respondents on all measured dimensions in the same time. However, in order to classify respondents based on dimensions used to form a multidimensional scale, separate dimensions need to be properly spaced to allow for getting a score for each dimension.

- Assessing the importance of each item included in the developed scale and assigning items' weight accordingly: items' weighting will not be necessary if all items are assumed to be equally important.
- Understanding the difference between inductive and deductive scaling methods: the difference between these methods is highly related to the starting point of developing the scale (i.e. whether the researcher starts with the concept that is going to be measured then determine the set of items which measures that concept or vice versa). In the inductive methods, scale items that go together are identified empirically by examining the pattern of responses on a set of measures to come up with the underlying concept they represent. In contrast, the deductive methods starts with a concept and then the tapping items will be selected or developed. However, items will be combined to form a suitable set of measures for the underlying concept based on the observed correlations between them.

Based on this description, this research activity is considered as deductive in nature since the factors of sustainable lean implementation identified from the literature were used to develop the components of the assessment tool and determine data analysis techniques. This tool has

been developed by using Likert scales, a simple unidimensional scales development method used widely (De Vaus, 2002; Likert, 1974). No weights have been assigned to the scale developed items since they were assumed to be equally important. More information about criteria that should be considered when selecting the items (i.e. statements) of the scale as well as scale construction and analysis can be found in (Likert, 1974) and (De Vaus, 2002).

The conducted literature review revealed that sustainability of successful lean implementation is determined based on the progress of an organization in achieving higher levels of:

- developing stabilized processes with well determined steps and predictable outcomes,
- updating process standards based on newly gained knowledge and newly identified forms of waste,
- developing a continuous flow of products/ services among various organizational processes towards the patient,
- creating error proofing processes to do things right the first time,
- improving organizational processes according to newly defined forms of wastes,
- enhancing leadership commitment to support process improvement throughout the whole organization,
- developing the organizational culture which promotes the accountability of employees and support their involvement in the process of defining and achieving better process performance levels aligned with stated organizational objectives,
- respect for employees, and

- adopting constructive change management process while transforming to lean organizational setup.

Thus, using lean-based terminology, sustainable lean implementation is highly affected by the following factors:

- Process stability
- Process standardization
- Patient flow streamlining
- Mistake Proofing
- Continuous improvement
- Leadership
- Culture and involvement
- Respect for employees
- Change management

Based on these identified factors, components of the LSAT of healthcare organizations have been designed.

In order to develop a balanced tool that evaluates the organizations' level of mastering lean activities and tools as well as the progress in developing lean-based cultural setup, the above stated critical success factors of sustainable lean implementation have been divided in two main sets of factors:

- Process Factors (factors that lead to process performance improvement while mastering various lean activities and tools):
    - Process stability
    - Process standardization
    - Patient flow streamlining
    - Mistake proofing
    - Continuous improvement
- Organizational Factors (factors that lead to enhance the organizational capabilities while developing staff cultural skills required to continuously improve the processes of their organization):
    - Leadership
    - Culture and involvement
    - Respect for employees
    - Change management

3.3 Questionnaire Sections

The lean sustainability assessment tool (LSAT) is made of two sections:

- Section one is addressed to quality management staff members of the hospital and includes questions about:
    - Hospital's demographic data,
    - Hospital's certification and accreditation status,

- Whether or not the hospital has used lean, six sigma, or lean six sigma for quality improvement and/or cost reduction purposes,
- Whether or not the hospital has adopted lean, six sigma, or lean six sigma in order to meet certification and/or accreditation purposes,
- Whether or not the hospital has recognized positive changes in both quality and cost levels of offered services due to implementing lean, six sigma, and/or lean six sigma,
- Whether or not the hospital has adopted lean on a hospital level or department level, and
- Approaches used by the hospital while transforming to a lean organization.

In order to make the developed tool usable for all hospitals, regardless of their level of lean adoption, respondents are directed through this section based on the current level of intervention with lean within their hospitals. In addition, the investigation about "change management" approaches, adopted while transforming to lean, is included in this section of the survey for the same reason. Data collected from this section are used for stratification purposes and for finding out the effect of accreditation/ certification status and the level of adopting other quality improvement initiatives on the observed sustainability level of lean implementation.

- Section two is addressed to all staff members of a surveyed hospital. It is composed of five components covering both lean process factors and organizational factors except the "change management" one which has been covered in section one. Questions under these components are written in five-point Likert scale format. In addition, this section includes

questions related to respondent's position, department, and familiarity with lean activities and tools presented in a check-list format. For analysis purposes and based on their response about their positions, respondents of this section are classified into three categories: managers, supervisors, and department staff members. Survey components of this section are:

- Lean process maturity (LPM): includes 19 questions about process stability and process standardization.
- Patient/ specimen pathway integration (PPI): includes 16 questions about various patient flow streamlining activities.
- Commitment to safety & continuous improvement (CSCI): includes 21 questions about mistake proofing and continuous improvement.
- Lean leadership commitment (LLC): includes 15 questions about leadership.
- Culture & involvement (CUIN): includes 28 questions about respect for employees and culture and involvement.

Questions, under each component of the developed tool, have been generated based on the characteristics of sustainable lean implementation described in literature (Alukal & Chalice, 2007; Caton-Hughes & Bradt, 2007; Dennis, 2002; Fine et al., 2009; Jones et al., 2006; Joosten et al., 2009; Jørgensen, Matthiesen, Nielsen, & Johansen, 2007; Leone & Rahn, 2010; Shuker, 2000; Spear & Bowen, 1999; Thompson et al., 2003; Zidel, 2006). In order to make the developed tool ready for the analysis techniques proposed below, all questions of section two are coded in a positive direction (i.e. they represent the desired conditions resulting from proper implementation of lean).

Not like many lean assessment tools available currently in literature, this tool focuses on both areas of sustainable lean implementation in addition to providing a way of measuring the level of organizational efforts conducted so far towards sustainable lean implementation. In addition, it uncovers the performance improvement area by investigating the results of implementing lean activities and tools instead of merely investigating the mastery of using these activities and tools without considering their effects in obtained results.

As the literature shows that the majority of lean implementation within healthcare organizations is conducted on a department level and only few healthcare organizations considered implementing lean on a hospital level, the developed survey is primarily designed to be used on a department level. However, it also can be used on a whole hospital level by conducting the developed survey on each department in the hospital and combining the responses for analyses and conclusions. In addition, the hospital departments' surveys within a single healthcare institute can be used for benchmarking and for identifying specific departmental needs which should be addressed to improve their level of lean implementation.

3.4 Validity of the Survey Instrument

A common definition of validity among researchers using survey instruments in their studies "is the extent to which the survey measure accurately reflects the intended construct." (Groves et al., 2004; p. 254) However, there is no specific method agreed upon for evaluating the validity of a developed survey instrument (De Vaus, 2002; Groves et al., 2004). Nonetheless,

there are several methods used traditionally to validate a developed survey tool. These methods are (De Vaus, 2002):

- Criterion validity,
- Content validity,
- Construct validity,
- Convergent validity, and
- Discrimination validity

For this study, the content validity method has been used to assess the validity of questions included in the developed survey tool. Using content validity method, the survey instrument is assessed by subject matter experts to find out to which extent it measures the various aspects of the underlying concept (De Vaus, 2002). Except for the demographic data questions, both sections of the first version of the LSAT were developed based on those characteristics found in the literature for a sustainable implementation of lean. This version included six questions under the first section and 111 questions under the second section. Questions of the second section were divided into nine components where each factor identified in the literature is assessed separately. However, by following (Groves et al., 2004) recommendations for developing attitude questions and self-administered questionnaires in addition to committee members' comments about the suitability of the content of the first version of the tool for the objective of the study, the second version of the tool was developed. In this version, number of questions of the first section increased to eight questions while number of questions in the second section was reduced to 99 questions. In addition, questions about change management approach used during lean transformation stage were moved to the first section of

the tool while questions of the second section have been distributed over five components, instead of nine, with titles and questions content wording suitable for healthcare organizations.

3.5 Population and Sample

The ideal case of utilizing the developed LSAT mandates the participation of all hospital staff members to:

- ensure their involvement in the implementation process and
- reflect their level of commitment towards achieving sustainable levels of lean implementation.

However, the objectives of this study can be achieved through using the convenient sampling technique to identify the respondents to both sections of the developed assessment tool. The population of the study is formed of all managers working at one of the non-profit hospitals in Florida. The hospital has more than 500 beds and more than 600 physicians. The total number of managers working at the hospital is 235. Using the convenient sampling technique, two members of the quality management department have been selected, to respond to the first section of the assessment tool, while 55 managers have been identified, to respond to the second section of the tool.

3.6 Survey Administration

Both sections of the developed tool have been prepared in an interactive PDF format in order to be distributed and returned through e-mail. Once a respondent completes filling out the designated LSAT section, he/she can click on the submission button included in the tool to have it sent back to the researcher. The data was collected over a two-month period. During that period and in order to achieve higher response rates, two reminders were e-mailed to survey respondents and two data collection sessions were conducted at one of the computer rooms at the hospital.

3.7 Response Rate

Both surveys of the LSAT first section, which were sent to members of quality management department, have been received while 15 responses were received from hospital managers about section two of the developed assessment tool. One of these responses was a duplicate which reduced the total responses of this section to 14 completed surveys. By this, the response rate to LSAT section one is 100% (total sample size is two) while the response rate to section two is 25.5% (total sample size is 55).

Both received surveys to the first section of the LSAT have missing responses to question 8 which investigates the level of hospital consideration of implementing lean as the management system of the whole hospital. Another missing response observed in these surveys is the total number of hospital staff members working in the hospital. Most of the responses to the

remaining part of these surveys were identical except for question 5 which is about the level of implementing lean, six sigma, and lean six sigma (i.e. on a hospital level or a department level) and the list of departments where these quality improvement initiatives have been performed.

Out of the 14 received responses to section two of the assessment tool, only one survey has a missing response to question number 19 of the "Lean Process Maturity" component (LPM19) of the LAST. Prior to analyzing this section, the Likert scale value of this question was substituted with the mode of the responses, given by the manager filling out that specific survey, to other questions of the "Lean Process Maturity" component of the assessment tool. Due to the fact that two of the received responses were originated from one department, the received 14 responses to section two of the LSAT represent 13 different departments of the hospital.

3.8 Reliability of the Survey Instrument

Since responses to section two of the LSAT are used to quantify the sustainability level of lean implementation in hospitals, the reliability analysis has been performed only on this section of the developed assessment tool. Based on the responses received to this section, the reliability measures of its various components have been calculated using the Cronbach's alpha (α) coefficient of internal consistency. As illustrated in Table 3.1, all Cronbach's α values are greater than 0.7. This indicates that the developed items of these components are highly reliable in measuring the underlying defined constructs.

Table 3.1 Summary of reliability analysis of section two of the LSAT

Component Name	Cronbach's α	Factors Group	Cronbach's α	Cronbach's α of the Assessment Tool
Lean Process Maturity (LPM)	0.917	Process	0.953	0.968
Patient/ Specimen Pathway Integration (PPI)	0.938			
Commitment to Safety & Continuous Improvement (CSCI)	0.871			
Lean Leadership Commitment (LLP)	0.902	Organizational	0.932	
Culture & Involvement (CUIN)	0.860			

However, the omitted item statistics, conducted by Minitab, showed low (<0.3), high (>0.8), and negative item adjusted total correlations of some of the items included under various components of the survey (Garson, 2011). These items are shown in Table 3.2 and they indicate, respectively, item's low, multicollinear, and reverse coded correlation with the sum of all remaining items included in Cronbach's α calculation (Garson, 2011). Nonetheless, omitting these items from the developed survey instrument did not show significant improvement in observed values of Cronbach's α. Thus, these items were included in the analysis due to the valuable information they represent in lean implementation assessment process.

Table 3.2 Low, high, and negative item adjusted total correlations as per the omitted item statistics conducted by Minitab

Component Name (Number of Items)	Items with Low Item Adjusted Total Correlation (<0.3)	Items with High Item Adjusted Total Correlation (>0.8)	Items with Negative Item Adjusted Total Correlation
Lean Process Maturity (19)	None	LPM2, LPM16	None
Patient/ Specimen Pathway Integration (16)	PPI1, PPI3	PPI5,PPI9, PPI12,PPI13, PPI14	None
Commitment to Safety & Continuous Improvement (21)	CSCI9, CSCI19	None	None
Lean Leadership Commitment (21)	LLC4, LLC11, LLC17	LLC1	None
Culture & Involvement (28)	CUIN7, CUIN10,CUIN16, CUIN18, CUIN19, CUIN20, CUIN23	None	CUIN6
Process Factors (LPM, PPI, CSCI) (56)	LPM11, PPI1, PPI3, CSCI8, CSCI18, CSCI21	LPM16	CSCI1, CSCI9, CSCI19
Organizational Factors (LLC, CUIN) (49)	LLC4, LLC17, CUIN18, CUIN20, CUIN23, CUIN28	None	CUIN6, CUIN7

3.9 Data Analysis Techniques

Data collected by section one of the developed assessment tool were used to study the effect of accreditation/ certification status and the level of adopting other quality improvement initiatives on the observed sustainability level of lean implementation. It also provided insight about the change management practices the surveyed hospital has adopted during its lean application journey.

Data collected by the second section of the assessment tool represented the major part of the conducted analysis. Components of this section were used to determine the sustainability level of lean implementation within the surveyed hospital. Such level has been determined according to the level of implementing process factors and organizational factors within each department of the surveyed hospital. This has been obtained by conducting the following steps:

- Each employee within each department rated the level of having various characteristics of sustainable lean implementation within his/her department. Each one of these characteristics was addressed as a separate question under its related survey component of section two of the LSAT. The result of this step was an **individual rating** of **individual characteristics** of sustainable lean implementation within a hospital department.
- Employees' responses to each question were combined for all those who work in the same department to determine the level of implementing each of the stated lean characteristics within each department. This has resulted in having a **combined rating** of **individual characteristics** of sustainable lean implementation within a hospital department.
- Combined ratings of individual characteristics, stated under the same survey component of the LSAT, were combined to obtain the level of implementing each component within a hospital department. This has resulted in having a **combined rating** of **combined characteristics of each survey component** of sustainable lean implementation within a hospital department.

- **The level of implementing process factors within a hospital department** was obtained by combining the responses to survey components related to these factors (i.e. LPM, PPI, and CSCI). Likewise, **the level of implementing organizational factors within a hospital department** was obtained by combining the responses to survey components related to these factors (i.e. LLC and CUIN).
- Finally, responses of various hospital departments to survey components related **to each set of factors** were combined in order to determine **the level of implementing process factors and organizational factors in a hospital level**.

According to the steps stated above, this can be classified as a multi-criteria group evaluation (i.e. decision making) setup. Thus, the analysis of section two of the developed LSAT mandates the utilization of techniques capable of obtaining various sets of individual measurements, from each department member, and then combining them in various levels (i.e. individual characteristics level, survey component level, and set of factors level) to assess sustainability of lean implementation in either a department level or a hospital level. However, since the responses of all department members are collected in the Likert scale response format, which is classified as ordinal data according to theory of measurement (Stevens, 1946); it seems to be infeasible to directly conduct such analysis. This is due to limitations on analysis techniques that could be performed on ordinal data.

As per (Roberts, 1994), using the geometric mean to combine ratings of *n* different experts who rate a set of alternatives in various characteristics is considered a safe meaningful merging function (i.e. the obtained geometric means of experts' ratings can be used for alternatives comparison), provided that the ratings are in a ratio scale format. Thus, the above

stated steps of analysis can be conducted, using the geometric mean, if the various employees' ratings, which are collected in a Liekert-scale format, are combined and presented in a ratio scale format. This can be done using Consensus, Dissension, and Agreement measures which have been developed by Wierman and Tastle, over the last five years, as mathematical measures which permit "a logical determination of dispersion around a category value" (Tastle & Wierman, 2007a; p. 532) of Likert scale collected data to reflect the level of group agreement (Wierman & Tastle, 2005; Tastle & Wierman, 2007a; Tastle & Wierman, 2008a). The three measures are common in providing a ratio scale measure, within the unit interval, about the agreement level of a population provided that the data have been collected using any ordinal scale among which is the Likert scale. However, the Consensus measure shows the level of population agreement in regards to the mean, median, or mode of the collected responses and the Dissension measure illustrates the level of dispersion in population collected responses around that mean, median, or mode of the categories of the Likert-scale response. Thus, these two measures are complement of each other (i.e. a complete consensus generate a Consensus measure value of 1 and a Dissension measure value of 0 and vice versa). In regards to the Agreement measure, it presents the level of population agreement with reference to a predetermined category of the Likert-scale response.

These measures have been originally developed within a group decision making setup (Tastle, Wierman, & Dumdum, 2005) and have been utilized in various setups which use Likert scale-based data collection tools. See for instance (Tastle, Russell, & Wierman, 2008), (Tastle & White, 2008), (Tastle & Wierman, 2008b), (Tastle, Boasson, & Wierman, 2009), (Tastle & Wierman 2009), (Tastle, 2009), and (Tastle, Abdullat, & Wierman, 2010).

The mathematical properties of Consensus and Dissension measures can be found in (Wierman & Tastle, 2005), (Tastle & Wierman, 2006b), and (Tastle & Wierman, 2007a) while various developmental stages and applications of the Agreement measure can be found in (Tastle et al., 2005), (Tastle & Tastle, 2006), (Tastle & Wierman, 2006a), (Tastle & Wierman, 2007b), and (Tastle & Wierman, 2008a). (Villaverde & Kosheleva, 2010) have justified the developed Consensus and Dissension measures by deriving them from fuzzy logic basic formulas. The authors also illustrated the role these measures might have in the field of education.

All the three measures are calculated based on the relative frequency distribution of respondents over Likert categories, of each Likert item, and the distances between these categories. When summing the responses of several Likert items (i.e. summing their relative frequencies on each Likert category), the Likert scale response is obtained.

Mathematical formulations of the three measures are (Tastle, 2009; Tastle et al., 2010):

$$Cns\ (X) = 1 + \sum_{i=1}^{n} p_i \log_2 \left(1 - \frac{|X_i - \mu_X|}{d_X}\right) \quad (1)$$

$$Dnt\ (X) = -\sum_{i=1}^{n} p_i \log_2 \left(1 - \frac{|X_i - \mu_X|}{d_X}\right) \quad (2)$$

$$Dnt\ (X) = 1 - Cns\ (X) \quad (3)$$

$$Agr\ (X|\tau) = 1 + \sum_{i=1}^{n} p_i \log_2 \left(1 - \frac{|X_i - \tau|}{2d_X}\right) \quad (4)$$

Where:

$Cns\ (X)$ is the Consensus measure

$Dnt\ (X)$ is the Dissension measure

$Agr\ (X|\tau)$ is the Agreement measure

$p_i = P(X_i)$ the relative frequency of outcome X_i where X_i ranges from 1 to 5

μ_X is the mean of X

d_X is the width of X, and $d_X = X_{max} - X_{min}$

τ is the target category (i.e. Strongly Agree, Agree, Neutral, Disagree, or Strongly Disagree)

For the purpose of this study, only the Agreement measure and the Dissension measure are going to be used. More specific, the agreement measure will be utilized to find out the agreement level of hospital employees in regards to "Strongly Agree" target category while the

Dissension measure will shade the lights on the dispersion level of the collected responses. The strong agreement of survey respondents to all questions of process factors or organizational factors will generate scores equal to 1 of the Agreement measure while their strong disagreement will generate scores equal to 0. If the responses are spread over the various categories of the Likert scale, the Agreement measure will have a value between 0 and 1. For the Dissension measure, the value of 1 indicates that 50% of the respondents are in the "Strongly Agree" category and 50% are in the "Strongly Disagree" category. The dissension measure will have the value of 0 when a complete consensus is achieved by survey respondents in regards to the rated factor (i.e. only one Likert category is selected by all respondents). However, in order to be, at least, 95% confident that the observed level of agreement is reached with a consensus level of 80% or more, the Dissension measure value must not exceed 20% (Tastle, 2009). The reason of using the Dissension measure, instead of the Consensus measure, in assessing the quality of the reported level of agreement is that the value of Dissension measure directly indicates the level of dispersion in the received responses without the need to state any central tendency related information. This is not the case with the Consensus measure (i.e. if we say the team has reached 80% level of consensus, we need to know on which category). In order to confirm this property of Tastle and Wierman Dissension measure, it has been compared with Leik's dispersion measure. This measure is described as "the purest ordinal measure of spread" (Weisberg, 1992; p. 67) since its obtained from the cumulative relative frequency distribution of responses over a set of ordinal categories independent of "sample size, number of choice options, central tendency, and assumptions about intervals between choice options." (Leik, 1966; p. 86). Although the Dissension measure is calculated from the relative frequency distribution, not from

the cumulative relative frequency distribution as Leik's Dispersion measure is calculated, both measures show no significant statistical difference in the dispersion level observed in a set of simulated Likert category responses at level of 0.05 α of Wilcoxon Signed rank test.

Table 3.3 Comparison of dispersion levels of simulated Likert category responses as obtained by Leik's Dispersion measure and Tastle and Wierman Dissension measure

CFD-Based (Leik, 1966)						RFD-Based (Tastle & Wierman, 2005)					
SD	D	N	A	SA	D	SD	D	N	A	SA	Dnt
0.2	0.4	0.6	0.8	1	**0.600**	0.2	0.2	0.2	0.2	0.2	**0.566**
0.5	0.5	0.5	0.5	1	**1.000**	0.5	0	0	0	0.5	**1.000**
0.1	0.4	0.7	0.9	1	**0.450**	0.1	0.3	0.3	0.2	0.1	**0.414**
0.9	1	1	1	1	**0.050**	0.9	0.1	0	0	0	**0.070**
0.8	0.9	1	1	1	**0.150**	0.8	0.1	0.1	0	0	**0.198**
0.1	0.2	0.3	0.9	1	**0.350**	0.1	0.1	0.1	0.6	0.1	**0.412**
0	0	0	0	1	**0.000**	0	0	0	0	1	**0.000**
0	0	0	1	1	**0.000**	0	0	0	1	0	**0.000**
0	0	1	1	1	**0.000**	0	0	1	0	0	**0.000**
0	1	1	1	1	**0.000**	0	1	0	0	0	**0.000**
1	1	1	1	1	**0.000**	1	0	0	0	0	**0.000**

Based on these properties of Tastle and Wierman measures, these measures can transfer team members' evaluation of multiple alternatives collected in Likert scale (i.e. ordinal) format into ratio scale format. Therefore, it will be safe to use the geometric mean of Agreement measure and Dissension measure resulting from combining the ratings of department employees and use them to determine the level of factors implementation. The remaining part of this section shows how this is applied throughout the study by using a hypothetical example. It also shows that the Agreement measures and Dissension measures obtained by summing the responses on several Likert items (i.e. summing their relative frequencies on each Likert category) to provide

the level of implementing a combine set of lean characteristics can generate values equal to those obtained by getting the geometric mean of the Agreement measures of the Likert items included.

A total of 80 staff members working at the radiology department of hospital X have responded to a survey instrument about the level of implementing lean within their department. The instrument is made of five components (i.e. Likert scales) each of which contains three questions (i.e. Liker items). Responses of staff members have been captured using five-point Likert categories (i.e. SD, D, N, A, SA) and a frequency table has been generated by tallying the number of responses per category for each question. Both Dissension measure and Agreement measure have been calculated for each question using formulas number 2 and 4 stated earlier. Since all questions of the survey instrument are written in a positive tone, the "SA" category has been selected as the target category used to calculate the Agreement measure. The obtained values of both measures are presented separately in Tables 3.4 and 3.5. In addition, Table 3.4 shows the Agreement measure for each survey component as well as each framework factor. Values of these measures are obtained by calculating the geometric mean of the measures of the related questions.

Table 3.4 The Agreement measure calculation sheet

Likert Items	Likert Categories					Agr(SA)	Survey Components	Geometric Mean Agr(SA)	Framework Factors	Geometric Mean Agr(SA)
	SD	D	N	A	SA					
LPM1	13	22	16	12	17	0.54	LPM	0.54	Process	0.54
LPM2	9	19	15	21	16	0.60				
LPM3	19	21	13	14	13	0.48				
PPI1	19	17	20	13	11	0.48	PPI	0.52		
PPI2	12	15	18	20	15	0.58				
PPI3	21	13	17	11	18	0.51				
CSCI1	13	16	18	14	19	0.57	CSCI	0.57		
CSCI2	17	18	10	15	20	0.55				
CSCI3	8	22	17	18	15	0.58				
LLC1	19	17	10	21	13	0.52	LLC	0.54	Organizational	0.54
LLC2	11	21	16	16	16	0.56				
LLC3	16	15	15	17	17	0.55				
CUIN1	14	15	18	16	17	0.57	CUIN	0.54		
CUIN2	18	14	12	15	21	0.56				
CUIN3	19	13	20	15	13	0.51				

For instance, Agr(SA) of LPM survey component is obtained by getting the geometric mean of Agr(SA) of LPM1, LPM2, and LPM3 while Agr of the process factors is obtained by getting the geometric mean of all Agr's of LPM, PPI, and CSCI questions.

Table 3.5 The Dissension measure calculation sheet

Likert Items	Likert Categories					Dnt
	SD	D	N	A	SA	
LPM1	13	22	16	12	17	0.55
LPM2	9	19	15	21	16	0.52
LPM3	19	21	13	14	13	0.58
PPI1	19	17	20	13	11	0.54
PPI2	12	15	18	20	15	0.52
PPI3	21	13	17	11	18	0.62
CSCI1	13	16	18	14	19	0.56
CSCI2	17	18	10	15	20	0.64
CSCI3	8	22	17	18	15	0.50
LLC1	19	17	10	21	13	0.60
LLC2	11	21	16	16	16	0.53
LLC3	16	15	15	17	17	0.58
CUIN1	14	15	18	16	17	0.55
CUIN2	18	14	12	15	21	0.64
CUIN3	19	13	20	15	13	0.55

However, tallying the staff members' responses to each survey component and each framework factor, instead of each survey question, represent another way to obtain the corresponding Agr values. This method will be denoted as the frequency distribution method of obtaining Agr values. Table 3.6 presents the obtained values using this method together with the values obtained by using the geometric mean. According to Wilcoxon Signed rank test, the values obtained by these two methods have no significant statistical difference at 0.01 α. The comparison between the two methods has been performed to support the use of the frequency distribution method in obtaining the values of Agr which is originally used by Tastle and Wierman in almost all of their papers. Not observing significant statistical difference among Agr values obtained by geometric mean method and frequency distribution method makes the later a safe technique for combining ratings of *n* different experts who rate a set of alternatives in various characteristics as the former is considered so by (Roberts, 1994).

Table 3.6 Frequency distribution-based vs. geometric mean-based values of Agr measure

Likert Scales		Likert Categories					Agr(SA)	Geometric Mean Agr(SA)
		SD	D	N	A	SA		
Survey Components	LPM	41	62	44	47	46	0.54	0.54
	PPI	52	45	55	44	44	0.53	0.52
	CSCI	38	56	45	47	54	0.57	0.57
	LLC	46	53	41	54	46	0.54	0.54
	CUIN	51	42	50	46	51	0.55	0.54
Model Factors	Process	131	163	144	138	144	0.54	0.54
	Organizational	97	95	91	100	97	0.54	0.54

Nonetheless, in order to use these measures on the collected responses using this method, the following conditions need to be satisfied:

- All questions of section two of the developed LSAT should be written in a positive tone.
- The Cronback's Alpha of each survey component is 0.7 or more (De Vaus, 2002; Gliem & Gliem, 2003).
- The Cronback's Alpha of Process Factors components combined is 0.7 or more.
- The Cronback's Alpha of Organizational Factors components combined is 0.7 or more.

Based on what has been illustrated earlier in sections 3.3 and 3.8, these conditions have been satisfied since all items of section two of the LSAT are written in a positive tone and the reliability analysis of the stated components of this section showed that they have more than 0.7 Cronback's alpha values.

CHAPTER 4 BASELINE FRAMEWORK AND IMPLEMENTATION

4.1 Lean Sustainability Assessment Framework

This section presents the proposed framework for lean sustainability assessment together with an illustration of how various efforts of healthcare organizations can be quantified based on the defined sets of critical success factors. It also presents the format of the recommendation report which is going to be provided to surveyed departments so they can develop their action plans accordingly. In addition, an illustration of framework application on simulated data sets will be provided to explore some of the analysis scenarios which might be observed when assessing sustainability of lean implementation in healthcare organizations. Finally, framework validation will be presented based on survey administration in one of U.S. hospitals in State of Florida together with a set of concluding remarks.

4.1.1 Framework Description

As shown in Figure 4.1, the main objective behind developing and implementing sustainable lean-based processes in a healthcare organization is to enhance patient satisfaction through improving the quality of its offered services. Such improvement can be achieved by eliminating process waste and creating continuous flow based on patient's pull, rather than push, mechanism.

By following the steps of the analysis techniques explained in chapter three, the collected LSAT responses of a surveyed hospital will generate the coordinates of its projection in the lean sustainability assessment space (LSAS). The process factors score, obtained from Lean Process Maturity (LPM), Patient Pathway Integration (PPI), and Commitment to Safety and Continuous Improvement (CSCI) survey components, represents the *x* coordinate while the organizational factors score, obtained from Lean Leadership Commitment (LLC) and Culture and Involvement (CUIN) survey components, represents the *y* coordinate.

Depending on the values of these two scores of a hospital, the sustainability of lean implementation in that hospital can be in one of the four zones of the LSAS. As illustrated in Figure 4.2, these zones are:

- Making Progress zone: where both process factors and organizational factors of sustainable lean implementation are considerably enforced within the analyzed organization,
- Commencing zone: where the organizational factors of sustainable lean implementation are more enforced than the process factors within the analyzed organization,
- Confounding zone: where the process factors of sustainable lean implementation are more enforced than the organizational factors within the analyzed organization, and
- Critical zone: where both process factors and organizational factors of sustainable lean implementation are insignificantly enforced within the analyzed organization.

The Making Progress zone is the only zone in which healthcare organizations are considered to have a sustainable level of lean implementation where both process and organizational factors

are significantly enforced within the organization. However, healthcare organizations in the remaining zones have unsustainable levels of lean implementation with different risk degrees.

Organizations in the Commencing zone encounter risk degrees less than those in Confounding and Critical zones. This is due to their high adoption level of organizational factors which have a significant effect in sustaining achieved improvements gained from implementing lean. Though, low adoption level of process factors reduces the effectiveness of improvement efforts conducted within these organizations. In order to move towards the Making Progress zone, these organizations need to master utilization of lean activities and tools through training and practice.

Despite the high adoption of process factors, lean improvement efforts conducted by organizations within the Confounding zone are inefficient enough due to the lack of adopting the organizational factors which develop the organization capabilities of sustainable lean implementation. Such organizations suffer from high levels of frustration caused by the huge efforts of conducting lean-based improvement activities while not achieving satisfactory levels of performance. If the missing organizational factors are not properly enforced, the lean initiative of these organizations is probably going to fail. However, the probability of failure of lean implementation in these organizations is higher than those organizations in the Commencing zone and lower than those in the Critical zone. Since organizations in the Critical zone have low levels of adoption of both process and organizational factors, they highly suffer from unsustainable lean implementation and need serious efforts to move to the Making Progress zone.

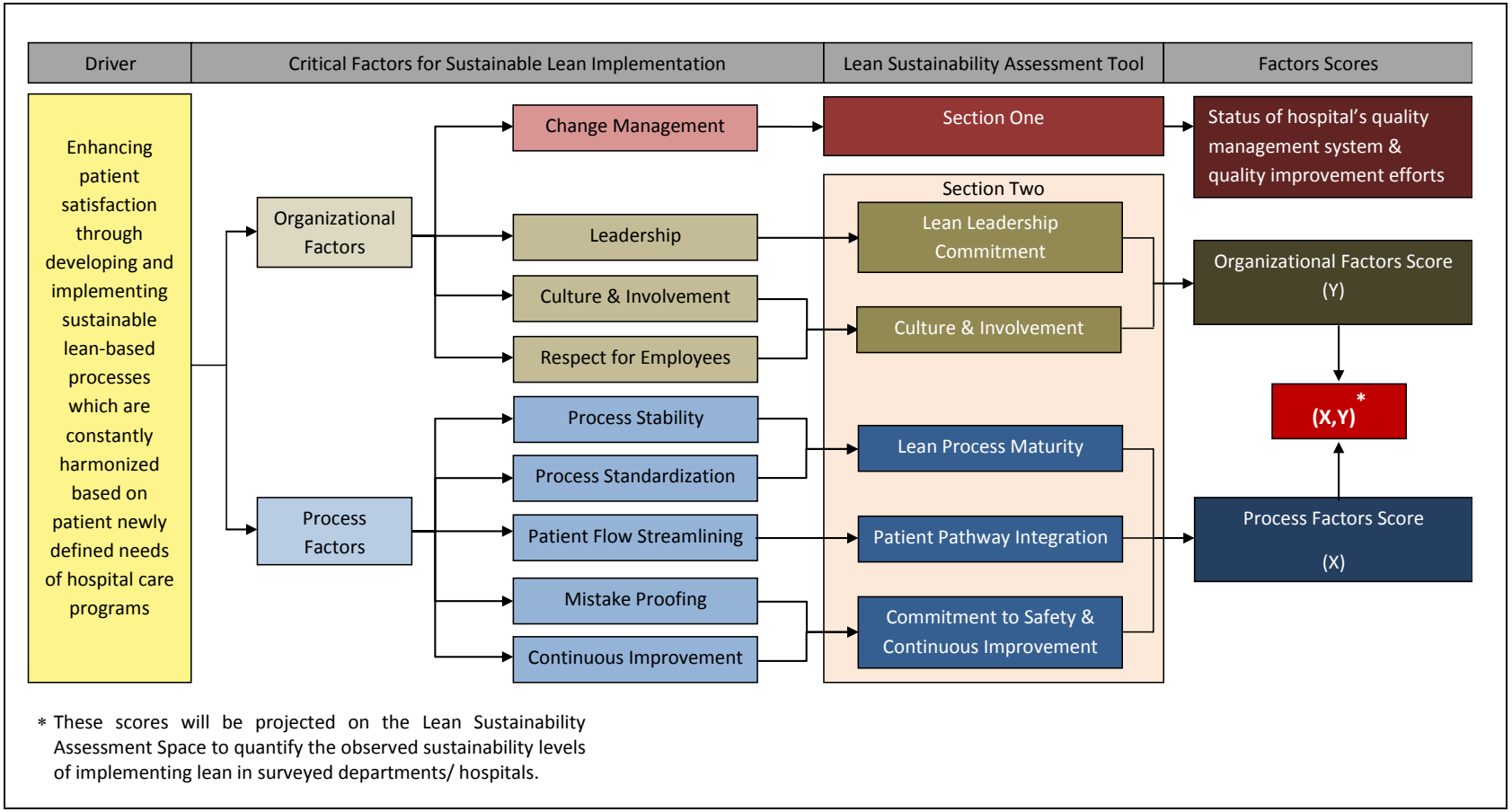


Figure 4.1 Lean sustainability assessment framework

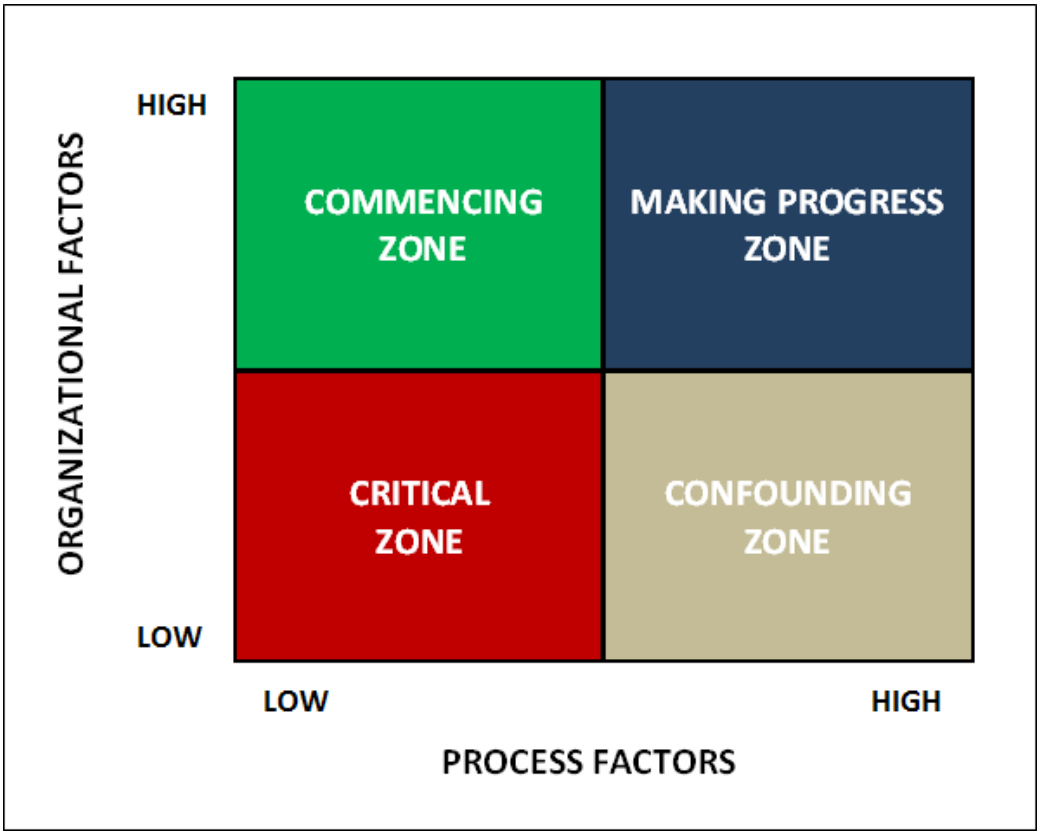


Figure 4.2 Lean sustainability assessment space (LSAS)

The developed lean sustainability assessment framework can be used by individual healthcare organizations as well as healthcare supervising authorities. The individual utilization of the framework helps the organizations diagnose the sustainability of their lean implementation efforts and define the missing factors to move to the Making Progress zone. The framework utilization by a national healthcare authority with several healthcare organizations under its supervision (e.g. ministries of health or corporate offices of hospitals' groups), provides a macro-level benchmarking tool to assess the progress of their supervised hospital towards implementing sustainable levels of lean. However, such benchmarking could take place within individual

organizations too, through comparing lean implementation efforts among their various departments.

4.1.2 Recommendations Report Format

In addition to providing factors' scores to locate a hospital in the LSAS, the LSAT provides the surveyed department/ hospital with information about the level of adopting various characteristics of sustainable lean stated under each survey component of the developed assessment tool. This information is presented in a radar chart format for all survey components as well as the set of questions included under each one of them. Based on this information, current gaps of sustainable lean implementation are identified and a specific factors implementation recommendations report is developed. This report is presented in a table format containing the desired conditions of various lean characteristics included in the LSAT in addition to their current level of implementation coded in colors and icons format. Both color coded icons and lean desired characteristics are shown in Tables 4.1 and 4.2 respectively. Implementation of suggested action plan to each surveyed department should follow the priority order inferred from the color coding in front of each lean characteristic of the recommendation report.

Table 4.1 Color and icon codes and action plan priority orders categorized by various levels of Agreement measures

Rating Code	Description	Action Plan Order of Priority
	Agr (SA) ≤ 0.2	1
	0.2 < Agr (SA) ≤ 0.4	2
	0.4 < Agr (SA) ≤ 0.6	3
	0.6 < Agr (SA) ≤ 0.8	4
	Agr (SA) ≥ 0.8	5

Table 4.2 Characteristics of sustainable lean categorized by the components and factors of the LSAT

Question Code	Factors Measured	Desired Conditions
LPM1	Process Stability	Give a designated name to each process in each department.
LPM2		For all processes in each department, assign a process owner(s) to be in-charge of conducting process training and assuring conformance to process performance standards.
LPM3		Define clearly both start and end points of each process in each department.
LPM4		Define clearly the outcomes of each process in each department.
LPM5		Define clearly the steps of each process in each department.
LPM6		Define clearly the sequence of process steps of each process in each department.
LPM7		Define clearly, the duration of process steps of each process in each department.
LPM8		Enroll hospital staff members in training sessions related to their process(es) to maintain the competence level needed to achieve defined process outcomes.
LPM9		Review staff scheduling for each process in each department to confirm the availability of the minimum number needed to achieve the defined process outcomes.
LPM10		Develop a schedule for conducting maintenance activities on all equipment utilized within each department . Whenever possible, shift some tasks of these activities from the maintenance team to the frontline staff.
LPM11		Review the amount of supplies related to each process in each department and define stock levels suitable to trigger the replenishment process of each item.
LPM12		Ensure the availability of process performing instructions at the point where process tasks are conducted.
LPM13		Ensure that all equipment, tools, and supplies needed to conducted each process in each department are either labeled or stored in designated labeled compartments. Arrange these items within the process operating area in a way that optimizes process operation.
LPM14	Process Standardization	Provide a visual illustration of process performance conditions by presenting their related instructions in a drawing or picture format.
LPM15		Develop a mechanism to capture the Tacit knowledge of hospital staff members in order to be included when developing newer versions of process performance standards.
LPM16		Design and update staff trainings according to the newly developed process performance standards applied at each department.
LPM17		Develop new process standards or update the existing ones as soon as new forms of waste (i.e. non-value adding activities) are identified.
LPM18		Follow a scientific-based improvement methodology (e.g. PDCA: Plan-Do-Check-Act) when developing/ updating standards of a process.

Question Code	Factors Measured	Desired Conditions
LPM19	**Process Standardization**	Target increasing staff utilization prior to increasing equipment utilization when developing/ updating standards of a process.
PPI1	**Patient Flow Streamlining**	Ensure the availability of resources (i.e. staff, supplies, data, and equipment) required to deliver a patient's defined value at the patient's point of care.
PPI2		Improve departments' response to drastic demand fluctuation in offered services through frequent adjustment of the workload level of each department.
PPI3		Develop the multitasking skills of department members, on continuous-basis, in order to respond to fluctuation in department workload and improve manpower utilization.
PPI4		Arrange various processes within each department to form a pathway sequenced according to a convenient patient/ specimen flow within the whole department.
PPI5		Ensure that all consecutive processes within each department patient/ specimen pathway(s) are directly connected.
PPI6		Ensure that all consecutive processes within each department patient/ specimen pathway(s) are linked based on a supplier-customer relationship.
PPI7		Ensure that all processes within each department patient/ specimen pathway(s) are directly connected to their internal and external suppliers.
PPI8		Establish a clear signaling mechanism between processes of each department and their suppliers so they can send requests and receive responses about resource requirements needed for delivering patient defined values.
PPI9		Synchronize all consecutive processes in each department pathway(s) to eliminate delays in tasks performed on patients/ Specimens.
PPI10		For all patient/ specimen pathways in each department, assign a pathway owner(s) to be in-charge of assessing the way of performing related task and assuring conformance to pathway performance standards.
PPI11		Ensure that Patient/ specimen pathway(s) within each department have a clearly defined start and end points at which they interface with other pathways in the hospital.
PPI12		Develop new department patient/ specimen pathway standards or update the existing ones as soon as new forms of waste (i.e. non-value adding activities) are identified.
PPI13		Coordinate with other hospital departments to ensure synchronization of patient/ specimen pathway(s) throughout the hospital.
PPI14		Coordinate with other hospital departments to develop new hospital patient/ specimen pathway standards or update the existing ones as soon as new forms of waste (i.e. non-value adding activities) are identified.

Question Code	Factors Measured	Desired Conditions
PPI15	Patient Flow Streamlining	Coordinate with other hospital departments to develop the integrated main pathways of the whole hospital.
PPI16		Coordinate with other hospital departments to ensure that main hospital pathways are formed based on patient's defined values.
CSCI1	Continuous Improvement	Engage hospital executives with various activities of continuous improvement initiatives conducted in the whole hospital throughout projects' sponsoring and support.
CSCI2		Engage hospital executives with a daily walk through different patient/specimen pathways within the whole hospital to identify new areas for improvement.
CSCI3		Engage department managers with a daily walk through different patient/specimen pathways within their departments to identify new areas for improvement.
CSCI4	Mistake Proofing	At each department, develop a simple comprehensive information display system through which department members can share the knowledge about the overall performance of their department.
CSCI5		Throughout the hospital, develop a simple comprehensive information display system through which hospital staff members can share the knowledge about the overall performance of the entire hospital.
CSCI6		Incorporate an inspection mechanism within the standards of each process in your department in order to inspect each process outcome(s) prior to proceeding to the next process (es).
CSCI7		Establish a feedback mechanism among all consecutive processes in your department to contain errors/ defects prior to have them spread into other hospital departments.
CSCI8		Encourage all hospital members to stop any process within the whole hospital and interrupt patient/ specimen pathway(s) upon observing the occurrence of an error or defect related to process desired outcomes.
CSCI9		Encourage all hospital members to stop any process within the whole hospital and interrupt patient/ specimen pathway(s) upon observing the occurrence of an error or defect related to patient safety.
CSCI10		Establish multidisciplinary teams to respond to process errors detected in the hospital in order to trace them to their ultimate root cause(s). These team must be made of all stakeholders in relation with affected process(es) .
CSCI11		Establish multidisciplinary teams to respond to safety incidents reported in the hospital in order to trace them to their ultimate root cause(s). These team must be made of all stakeholders in relation with incidents' causing process(es).
CSCI12		Educate hospital members about their line of support (i.e. supervisors and/or managers) whom they should contact when their process(es) go out of control.
CSCI13		Establish a clear signaling mechanism that help hospital members convey their support requests to their line of support in a direct manner.

Question Code	Factors Measured	Desired Conditions
CSCI14	Mistake Proofing	Establish a standard procedure for handling support related requests (i.e. response time, team members who should attend within each hospital zone, and any other alternative plans if needed) for each process within the entire hospital.
CSCI15	Continuous Improvement	Educate hospital members to follow a scientific-based improvement methodology (e.g. PDCA: Plan-Do-Check-Act) when conducting any continuous improvement related efforts within their departments.
CSCI16		Train all hospital members on the continuous improvement method adopted by the hospital.
CSCI17		Ensure that all continuous improvement efforts performed by hospital members are made to advance one or more of the hospital's strategic objectives.
CSCI18		Ensure that all continuous improvement efforts performed by hospital members have clearly expected outcomes.
CSCI19		Ensure that all continuous improvement efforts performed by hospital members are conducted under the guidance of a teacher (i.e. a process owner).
CSCI20		Establish a suggestion program through which continuous improvement ideas flow from staff towards hospital management.
CSCI21		Establish a mechanism that regularly updates hospital management with the results of continuous improvement efforts conducted by staff members.
LLC1	Leadership	Hospital executives should establish a clear vision about the meaning of "process perfection" and has it shared with all staff members.
LLC2		Hospital executives should establish a clear vision about "what constitutes patient's needs" and has it shared with all staff members .
LLC3		Develop hospital strategic objectives based on patients' defined needs (i.e. values).
LLC4		Develop patient-centered hospital strategic objectives with clear goals related to advancing the productivity level of hospital processes.
LLC5		Develop patient-centered hospital strategic objectives with clear goals related to advancing the quality level of hospital processes.
LLC6		Develop patient-centered hospital strategic objectives with clear goals related to reducing the cost of hospital processes.
LLC7		Develop patient-centered hospital strategic objectives with clear goals related to reducing both lead and processing time of hospital processes.
LLC8		Develop patient-centered hospital strategic objectives with clear goals related to advancing the safety level of hospital processes.

Question Code	Factors Measured	Desired Conditions
LLC9	Leadership	Develop patient-centered hospital strategic objectives with clear goals related to improving the environmental setup of hospital processes.
LLC10		Develop patient-centered hospital strategic objectives with clear goals related to improving the morale level of hospital staff, patients, and suppliers.
LLC11		Hospital executives should establish measures to reflect the performance of the entire hospital towards achieving hospital strategic objectives.
LLC12		Department managers should establish measures to reflect the performance of their departments towards achieving hospital strategic objectives.
LLC13		Establish a mechanism to measure advancement towards fulfilling hospital strategic objectives on a daily basis.
LLC14		Establish a mechanism that enhances the awareness of all department members about hospital strategic objectives.
LLC15		Ensure that the developed hospital strategic goals are challenging enough to convey the right level of urgency needed to motivate for endless improvement cycles towards perfection.
LLC16		Establish a mechanism to transform hospital strategic objectives into actionable plans for each department in the hospital.
LLC17		Ensure that the developed departmental actionable plans have goals and objectives challenging enough to convey the right level of urgency needed to motivate for endless improvement cycles towards perfection.
LLC18		Establish a mechanism to transform hospital strategic objectives into specific responsibilities and performance targets for each staff member in the hospital.
LLC19		Enforce the "Control Department Concept" among various hospital departments (i.e. each department is accountable for coordinating the efforts of different departments involved in achieving cross-functional goals which falls under its specific plan for achieving the hospital's strategic objectives).
LLC20		Establish a mechanism to encourage hospital departments to consider supporting the cross- functional goals of other departments when developing the plan of their own departments.
LLC21		Hospital executives should incorporate plans of all departments into one master plan to assure their alignment towards achieving defined strategic objectives.
CUIN1	Culture & Involvement	Establish educational activities and arrange regular departmental events to promote, among hospital staff members, the understanding of Lean as a business philosophy which creates value through creating trust and fulfillment.
CUIN2		Establish educational activities and arrange regular departmental events to promote, among hospital staff members, the understanding of Lean as more than waste elimination and cost reduction.

Question Code	Factors Measured	Desired Conditions
CUIN3	Culture & Involvement	Establish educational activities and arrange regular departmental events to promote, among hospital staff members, the realization of continuous improvement initiatives as efforts conducted to attack problems and processes not people.
CUIN4		Establish educational activities and arrange regular departmental events to promote, among hospital staff members, the realization of process continuous improvement as a way of work and not just a quality initiative.
CUIN5		Establish educational activities and arrange regular departmental events to promote, among hospital staff members, that process redesign should be based on patient's defined needs.
CUIN6		Conduct basic and refreshing training sessions, regular quality circle discussions, and encourage participation in continuous improvement events to enhance hospital members capabilities of identifying patient needs and developing countermeasures or solutions required to fulfill them.
CUIN7		Conduct basic and refreshing training sessions, regular quality circle discussions, and encourage participation in continuous improvement events to enhance hospital members capabilities of identifying different types of waste which constitutes non-value adding activities within their processes.
CUIN8		Ensure that Lean training sessions are properly structured to progressively improve department members' understanding about various Lean activities and tools and how they can be applied to their daily performed activities.
CUIN9		Encourage department members to continuously participate in improvement projects related to their processes.
CUIN10	Respect for Employees	Develop a mechanism to ensure the engagement of hospital staff members with simultaneous doing and learning infinite cycles in order to enhance their Lean leadership skills.
CUIN11		Encourage hospital members to develop and improve standards related to their processes.
CUIN12		Encourage hospital members to utilize their creativity to gradually improve their processes prior to jumping to capital investment solutions.
CUIN13		Enforce the accountability of hospital members for conducting continuous improvement initiatives to solve specific problems related to their processes.
CUIN14	Culture & Involvement	Establish a mechanism to ensure the involvement of hospital supervisors, managers, and executives in process improvement activities through providing necessary support to various department members.
CUIN15		Establish a mechanism to ensure that all problem solving and continuous improvement activities are conducted by multidisciplinary teams made of all stakeholders affected by developed solutions and/ or redesigned process(es).

Question Code	Factors Measured	Desired Conditions
CUIN16	**Respect for Employees**	Establish a mechanism to ensure that all problem solving and continuous improvement teams are formed from frontline hospital staff members (i.e. nurses, technicians, and allied health personnel) with the support of supervisors and managers from all levels of the hospital.
CUIN17	**Culture & Involvement**	Establish a mechanism to ensure that all problem solving and continuous improvement teams have at least one member of the hospital executive team as a champion.
CUIN18		Encourage establishing the practice of regular meetings of a group of members within each department to identify areas for improvement within the department.
CUIN19		Encourage establishing the practice of regular meetings of a group of hospital staff members from different departments to identify new areas for improvement throughout the whole hospital.
CUIN20		Establish a mechanism to ensure that there is at least one representative from each department attending hospital meetings for identifying various areas for improvement.
CUIN21	**Respect for Employees**	Establish a suggestion program through which staff members can deliver their ideas for improvement to hospital management.
CUIN22		Ensure that the hospital suggestion program has a mechanism for prioritizing implementation of staff suggestions based on their relevance to hospital strategic objectives.
CUIN23		Ensure that the hospital suggestion program has a mechanism for expediting implementation of staff suggestions, even if they are sub-optimal, based on their relevance to hospital strategic objectives.
CUIN24		Establish a clear performance-based reward and recognition program to value staff participation in process continuous improvement activities conducted in the hospital.
CUIN25		Ensure that department members are rewarded based on the number of continuous improvement suggestions they submit annually.
CUIN26		Ensure that department members are rewarded based on the number of continuous improvement events they attend annually.
CUIN27		Establish a mechanism to ensure that hospital staff members released from a process, due to improving manpower utilization, are redeployed to other value adding processes in the hospital.
CUIN28		Establish a mechanism to ensure that hospital has training and career advancing policies based on equal skill development opportunities for all hospital staff members.

4.2 Framework Implementation and Results (Group of Hospitals' Simulated Data)

In order to show how the developed framework is applied to a group of hospitals, a simulated response of nine hospitals generated from a set of uniform distributions with various ranges of X_i values. As shown in Table 4.3 below, it is assumed that each of the first five hospitals has 80 staff members working at five different departments. Each department has 16 employees divided into three groups according to their positions: a manager, three supervisors, and twelve frontline staff members. Similarly, each of the last four hospitals has 100 staff members distributed over five departments where each department has 20 employees divided into three groups: a manager, three supervisors, and sixteen frontline staff members. Due to the limited meaningfulness of fully analyzing the data resulting from these simulated responses, results presented in this section will be thorough enough to reflect the usefulness of the developed framework and show different analysis scenarios that might be observed in results obtained from real life sets of data.

Table 4.3 Simulated data for illustrating the application of the proposed framework

Hospital(#)	Department	Staff Position A(Manager)/ B (Supervisor)/C (frontline staff)
A(80)	A(16)/B(16)/C(16)/D(16)/E(16)	A(1)/B(3)/C(12)
B(80)	A(16)/B(16)/C(16)/D(16)/E(16)	A(1)/B(3)/C(12)
C(80)	A(16)/B(16)/C(16)/D(16)/E(16)	A(1)/B(3)/C(12)
D(80)	A(16)/B(16)/C(16)/D(16)/E(16)	A(1)/B(3)/C(12)
E(80)	A(16)/B(16)/C(16)/D(16)/E(16)	A(1)/B(3)/C(12)
F(100)	A(20)/B(20)/C(20)/D(20)/E(20)	A(1)/B(3)/C(16)
G(100)	A(20)/B(20)/C(20)/D(20)/E(20)	A(1)/B(3)/C(16)
H(100)	A(20)/B(20)/C(20)/D(20)/E(20)	A(1)/B(3)/C(16)
I(100)	A(20)/B(20)/C(20)/D(20)/E(20)	A(1)/B(3)/C(16)

According to the simulated response generated for these nine hypothetical hospitals, as if they responded to the developed LSAT, these hospitals vary in the level of adopting process factors and organizational factors necessary for sustainable lean implementation. Figure 4.3, below, shows that five of the surveyed hospitals are in the Making Progress zone (A, B, E, H, and I), two in the Critical zone (F and G), one in the Commencing zone (C), and one in the Confounding zone (D) of the LSAS. These levels are determined according to the level of staff members' agreement about the level of adopting lean characteristics of sustainable lean within their hospitals. Hospitals within Making Progress zone and Critical zone fall in a wide spectrum of factors scores. Thus, recommendations to these hospitals are expected to vary accordingly.

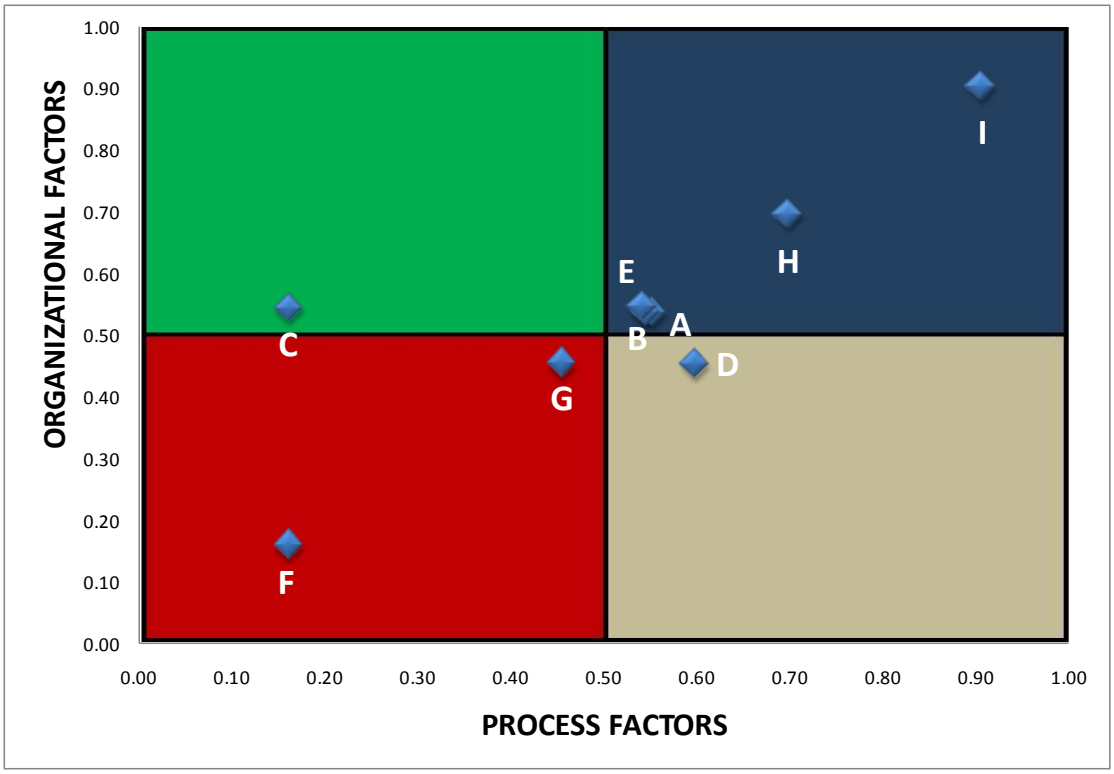


Figure 4.3 The LSAS of all simulated hospitals

Associated with the LSAS presented in Figure 4.3, there is Figure 4.4 which adds more insight to the observed levels of factors' adoption within these hospitals. This figure presents the level of factors adoption classified by the components of the LSAT. Similar to what has been presented in Figure 4.3, the figure shows that all LSAT components are highly adopted by hospitals A, B, E, H, and I, while these factors are less enforced in hospitals F and G. In addition, the figure shows that hospitals C and D has a high level of adopting the LSAT components which are either related to the process factors scores (LPM, PPI, CSCI) or the organizational factors scores (LLC and CUIN) while lacking the adoption of the remaining components.

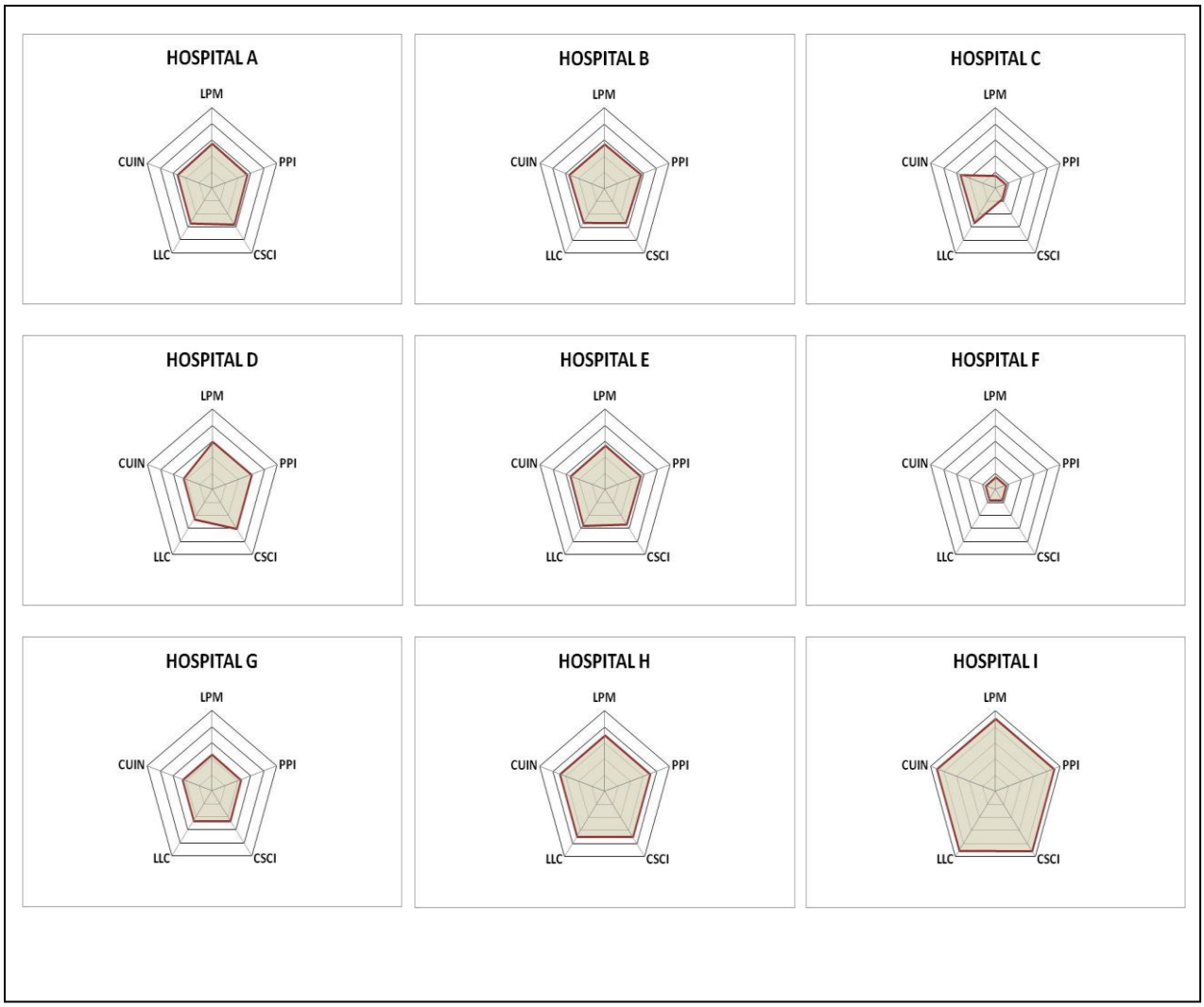


Figure 4.4 The LSAT radar chart of all simulated hospitals

Despite the valuable information presented in these two figures based on the Agr measure related analysis, it is equally valuable to analyze the level of dispersion observed in reported levels of factors' adoption. Such analysis is conducted by obtaining the Dnt measure for each lean characteristic stated under each LSAT component and present it in a radar chart format together with the observed levels of agreement. The radar chart presenting these measures is

made of five circles covering the range from 0 to 1 with a 0.2 increment. For illustration, the outer tan area which is surrounded in red in Figure 4.5 represents the level of implementing all lean characteristics stated under each component of the LSAT in hospital I while the inner red area surrounded in blue shows the level of dispersion observed while responding to questions related to each characteristic. The figure shows that almost all lean characteristics are implemented in hospital I with a level of 0.9 (or 90%) while the observed level of dispersion in reported levels of adopting these characteristics is 0.2 (or 20%).

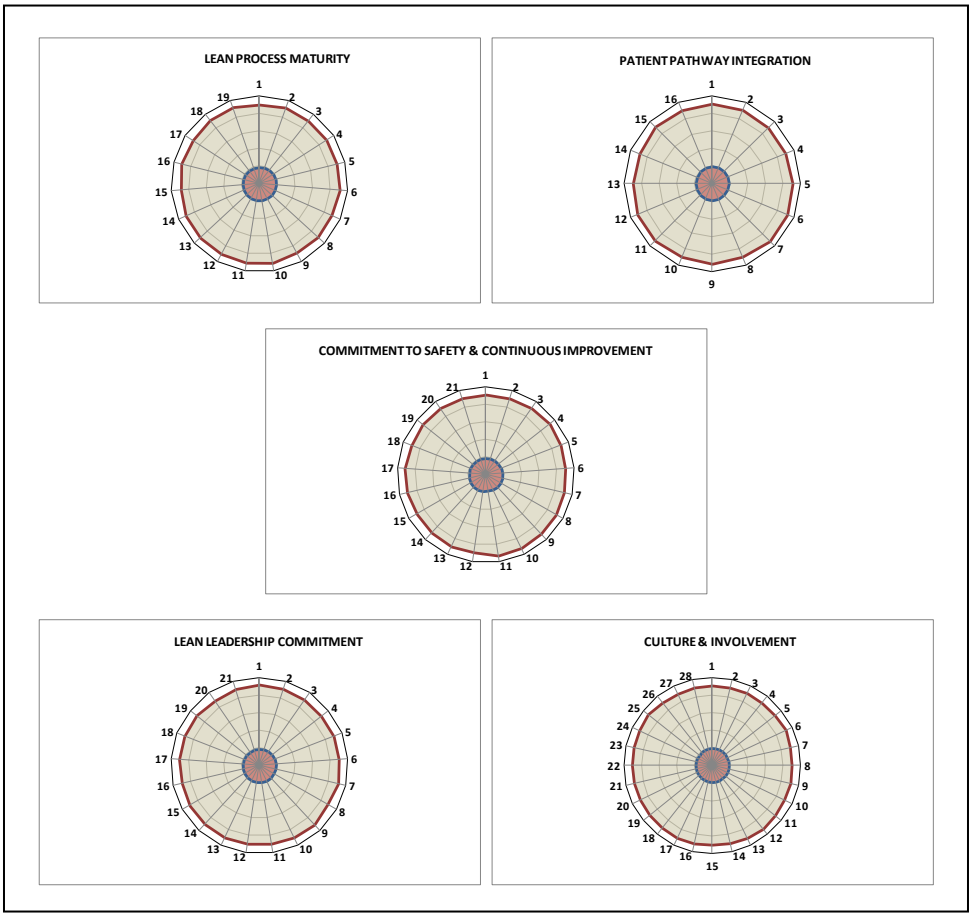


Figure 4.5 The LSAT radar chart of hospital I individual survey components

Whether or not the observed level of dispersion is ≤ 20% (i.e. within the inner circle of the radar chart) determines the level of analysis required to identify the level of implementing sustainable lean characteristics within the departments of a surveyed hospital. For instance, since hospital I has a Dissension measure equals to 20% for all LSAT components, it can be inferred that:

- the hospital staff members have a significant level of agreement, more than 80% with 95% confidence level, about the current level of implementing lean characteristics in their hospitals,
- the hospital radar chart, which illustrates the level of implementing process factors and organizational factors categorized by lean charctersitcs of each survey component, can be used to represent level of implementing these factors in each department of the hospital, and
- only one set of recommendations needs to be provided to all departments of the hospital.

Figure 4.6 confirms this conclusion since the radar charts of hospital I departments and its various hospital groups have the exact shape of the radar chart of the LSAT components of the whole hospital.

Figure 4.6 The LSAT radar chart of hospital I and its departments and groups of staff

If the observed dispersion level is more than 20%, more analysis will be needed to identify the sources of variation that have been observed. This is the case of hospital D, for instance, where Figure 4.7 shows how the level of dispersion is close to or even larger than level of reported agreement about level of implementing various characteristics of sustainable lean within this hospital. The remaining part of this section illustrates the level of analysis required for such cases through analyzing the response generated for hospital D and its various departments.

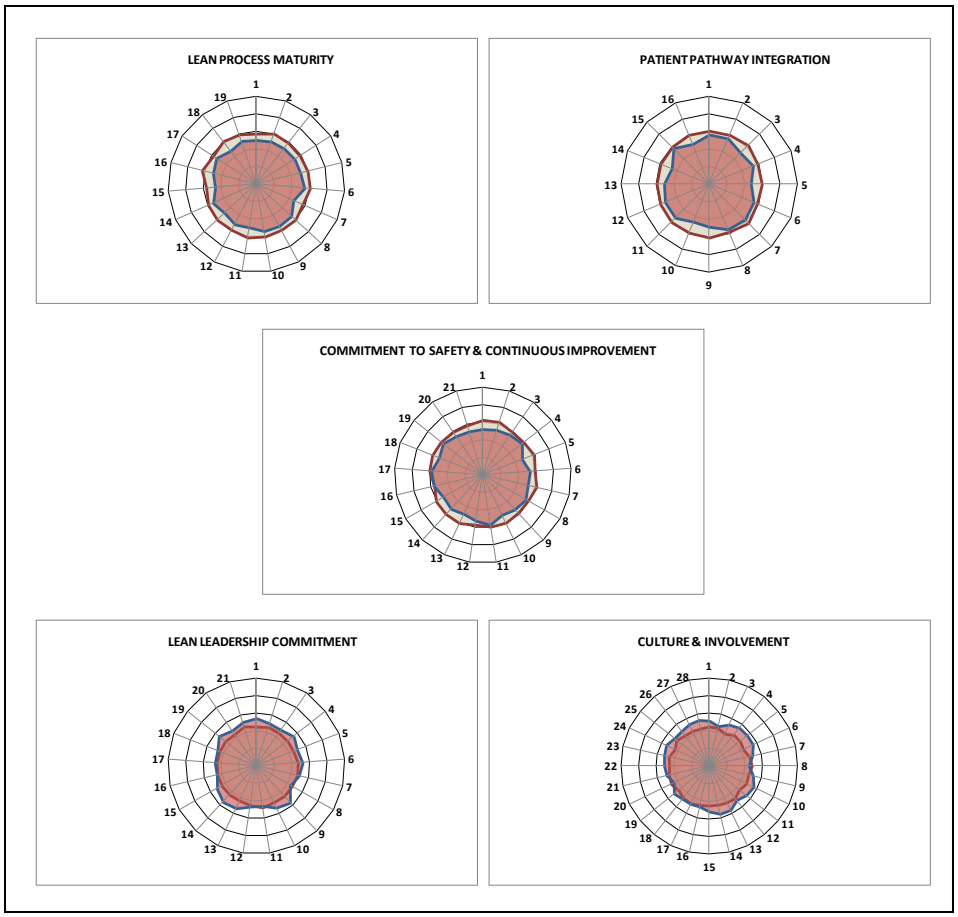


Figure 4.7 The LSAT radar chart of hospital D individual survey components

From Figure 4.3, hospital D resides in the Confounding zone of the LSAS with 0.6 process factors score and 0.45 organizational factors score. Figure 4.7 shows that the level of dispersion observed in hospital D's staff responses in regards to the level of adopting lean characteristics of LAST components is a little more than 50% but less than 60%. Therefore, further analysis needs to be conducted. Figure 4.8 shows the factors scores of all departments of hospital D while Figure 4.9 shows these scores for various staff groups of the same hospital. According to these factors scores, Departments A and D are in the Critical zone, departments B

and C are in the Making Progress zone, and deprtment E is in the Confunding zone of the LSAS. When looking at Figure 4.9, it can be seen that the factors scores of group A (i.e. managers) is much lower than the scores of groups B and C (i.e. supervisors and frontline staff).

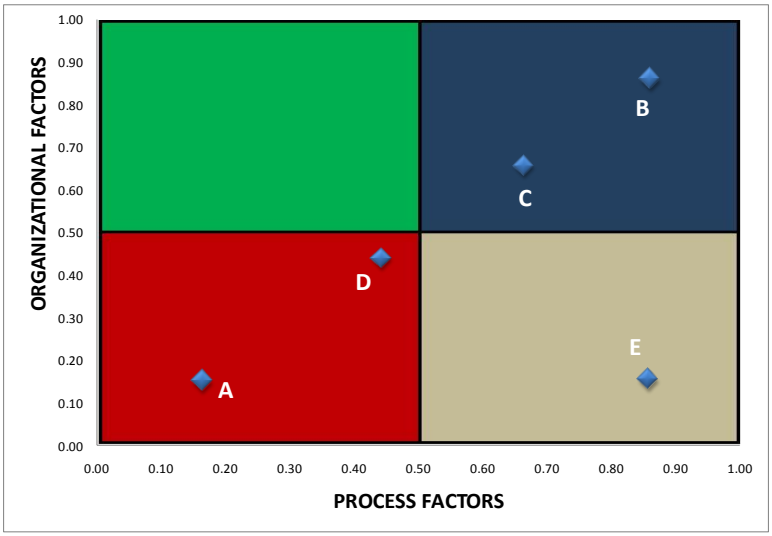


Figure 4.8 The LSAS of simulated departments at hospital D

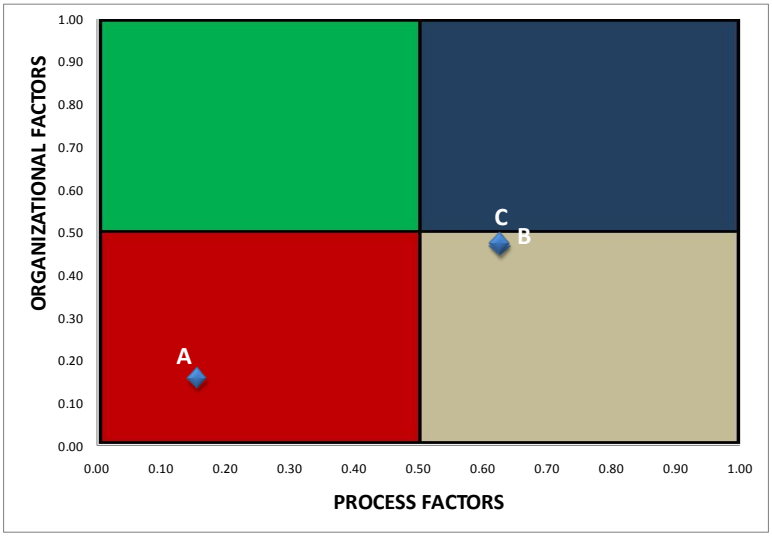


Figure 4.9 The LSAS of simulated groups of staff at hospital D

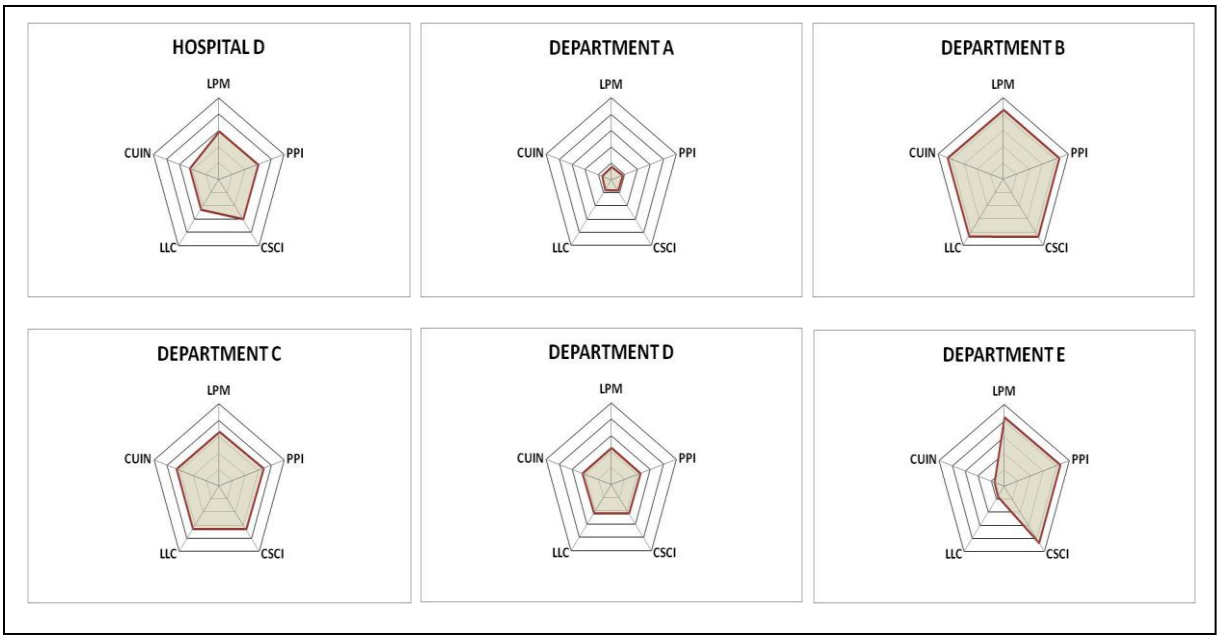


Figure 4.10 The LSAT radar chart of hospital D and its departments

By looking at the radar chart of each department, Figure 4.10 above, all components of the LSAT are variably implemented in department B (higher than 80%) followed by departments C (around 63%), D (41%), and A (around 20%). The distortion observed in the radar chart of hospital D is highly due to the level of implementing various lean characteristics in department E. This department has high scores of process factors components (more than 80%) and low scores in organizational factors components (Less than 20%).

The level of implementing all lean characteristics stated under each component of the LSAT in all departments of the analyzed hospital is presented in Figure 4.11. In addition to illustrating what has been concluded from Figure 4.10, this figure shows the level of dispersion observed in the reported adoption levels of lean characteristics of LSAT components. The figure shows that all members of department A are in agreement with the reported levels of adopting

lean characteristics within their department since the dispersion levels is around 20% (i.e. within the inner circle of the radar chart). It also shows, based on the observed levels of dispersion, that members of departments C and D have high levels of agreement in regards to most of the assessed lean characteristics while members of department B have a noticed disagreement about the level of adopting the assessed lean characteristics within their department. In regards to members of department E, the figure shows that they are in agreement about the level of adopting organizational factors related characteristics while they are in disagreement about the level of adopting process factors related lean characteristics.

Constructing these charts according to the perception of various groups of hospital staff members provides more insight to further investigate the source of observed dispersion in received responses about levels of adopting lean characteristics in hospital D. Figure 4.12 shows that groups A, representing managers of hospital D, are in agreement about the reported levels of lean characteristics adoption within the whole hospital. However, groups B and C, representing, respectively, hospital D supervisors and frontline staff members, have considerably higher levels of disagreement about the level of adopting these characteristics. In addition, the figure shows a remarkable difference about the level of perception of group A compared to groups B and C with regard to levels of adopting lean characteristics in hospital D.

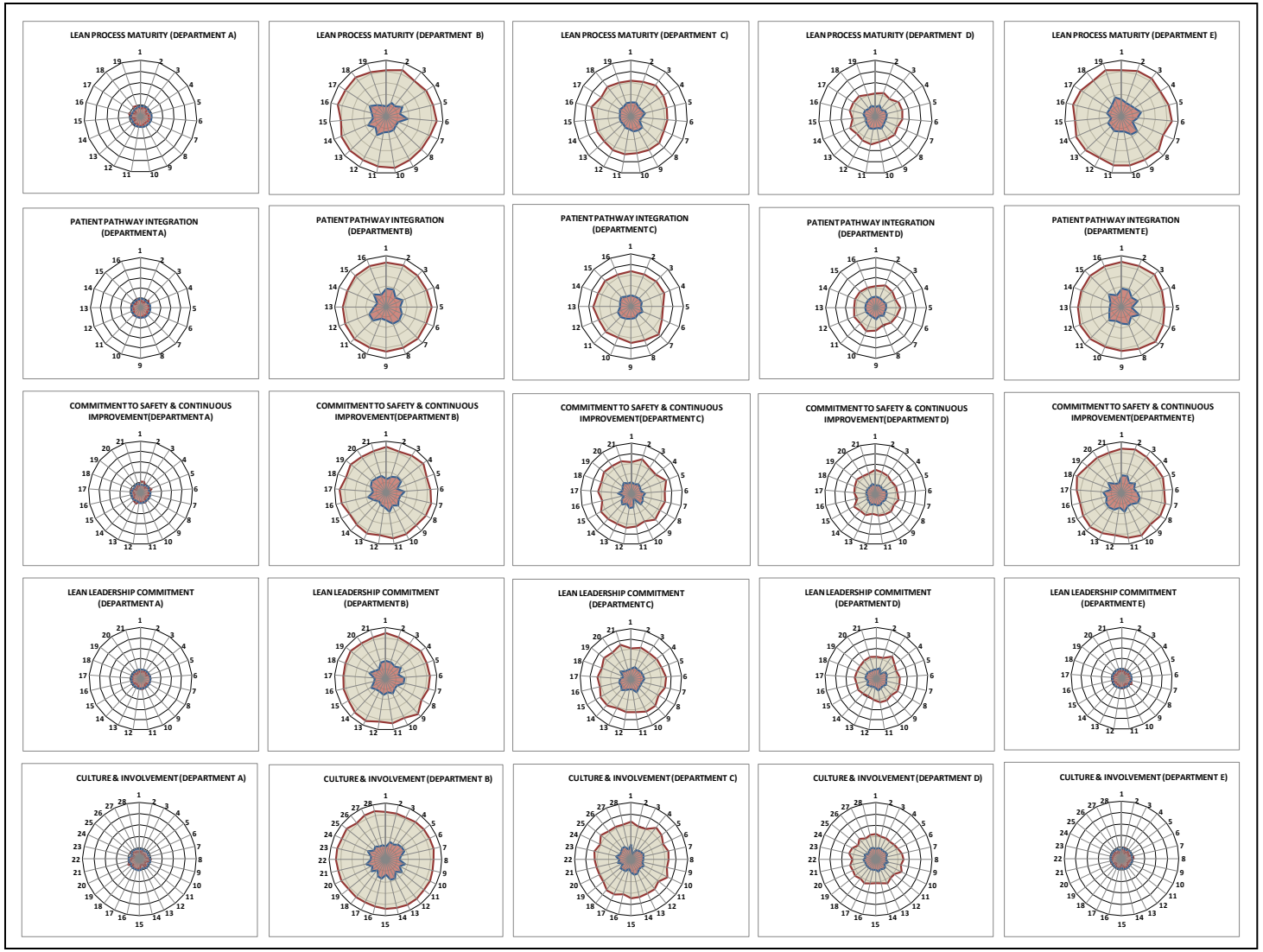


Figure 4.11 The radar chart of individual survey components of departments of hospital D

Figure 4.12 The radar chart of individual survey components of staff groups of hospital D
Legend: Group A = Managers Group B = Supervisors Group C = Frontline Staff

Based on lean characteristic implementation levels observed in Figure 4.11, a recommendation report will be generated for each department in hospital D. This report is composed of the desired conditions of various lean characteristics included in the LSAT, Table 4.2, in addition to their current level of implementation coded in colors and icons format presented earlier in Table 4.1. This report has not been generated for the simulated data of this section. However, a similar report has been presented at the end of the next section while concluding the analysis of the real data collected from one of the hospitals in State of Florida.

4.3 Framework Application and Results (A Single Hospital Real Data)

This section illustrates the application of the developed framework in one of the U.S. hospitals in State of Florida to determine its sustainability level of adopting various characteristics necessary for successful lean implementation. However, prior to start the illustration of the framework application, some information will be presented about the hospital's accreditation status, level of interaction with lean and other quality improvement initiatives, departments where these initiatives have been executed, and the awareness level about various lean activities and tools.

The hospital is accredited by the Joint Commission (TJC), "an independent, not-for-profit organization" that accredits U.S. healthcare organizations based on their "commitment to meeting certain performance standards" (*The Joint Commission*, 2011), and the ANCC Magnet Recognition Program, one of the American Nursing Credentialing Center (ANCC) programs which "recognizes healthcare organizations that provide the very best in nursing care and

professionalism in nursing practice" (*American Nurses Credentialing Center*, 2011). The hospital accreditation history by TJC started in 1997 while the ANCC Magnet hospital designation started in 2003.

Hospital's experience with lean, six sigma, and lean six sigma started in 2002, under what was called rapid improvement process, without any established link between these initiatives adoption and meeting any accreditation requirements. Despite the fact of adopting all the three quality improvement initiatives within various hospital departments, positive changes in both quality improvement and cost saving were recognized in hospital offered services due to implementing six sigma and lean six sigma only. The adoption levels of these two initiatives were on department level while they have not yet been considered to be adopted in hospital level. For instance, six sigma and lean six sigma were applied to the following hospital services:

- Clinical Services: emergency rooms, operating rooms, inpatient units, and outpatient and ambulatory units.
- Ancillary Support Services: admission and discharge, radiology and imaging, laboratory services, pharmacy and pharmaceutical services, sterilizing and reprocessing, and patient transportation.
- Nonclinical Support Services: purchasing and supply and information system.

Although the hospital did not implement lean as a management system of the whole hospital, the following approaches, usually adopted by lean organizations during transformation stage, have been observed:

- Recruiting external consultant to guide the organization while applying lean,
- Relying on internal expert(s) to guide the organization through various stages of lean application,
- Providing lean basic training to hospital executives, managers, and supervisors before starting lean application, and
- Starting lean application gradually throughout the organization by first selecting a department or a process where results of lean initiatives can be easily and promptly discerned.

Hospital managers responding to section two of the LSAT showed a considerable variation in their level of awareness about lean activities and tools listed in the assessment tool. This variation is presented in Figure 4.13 below. Among those lean activities and tools included in the study, waste elimination, continuous improvement, five whys, value stream mapping, types of waste, and five S's were known to 80% or more of the responding managers. However, lean activities and tools like kanban, continuous flow, error proofing, process capability, work standardization, pull, jidoka, and just-in-time were recognized by at least 50% of the managers while at least 20% of them recognized the remaining activities and tools included in the study.

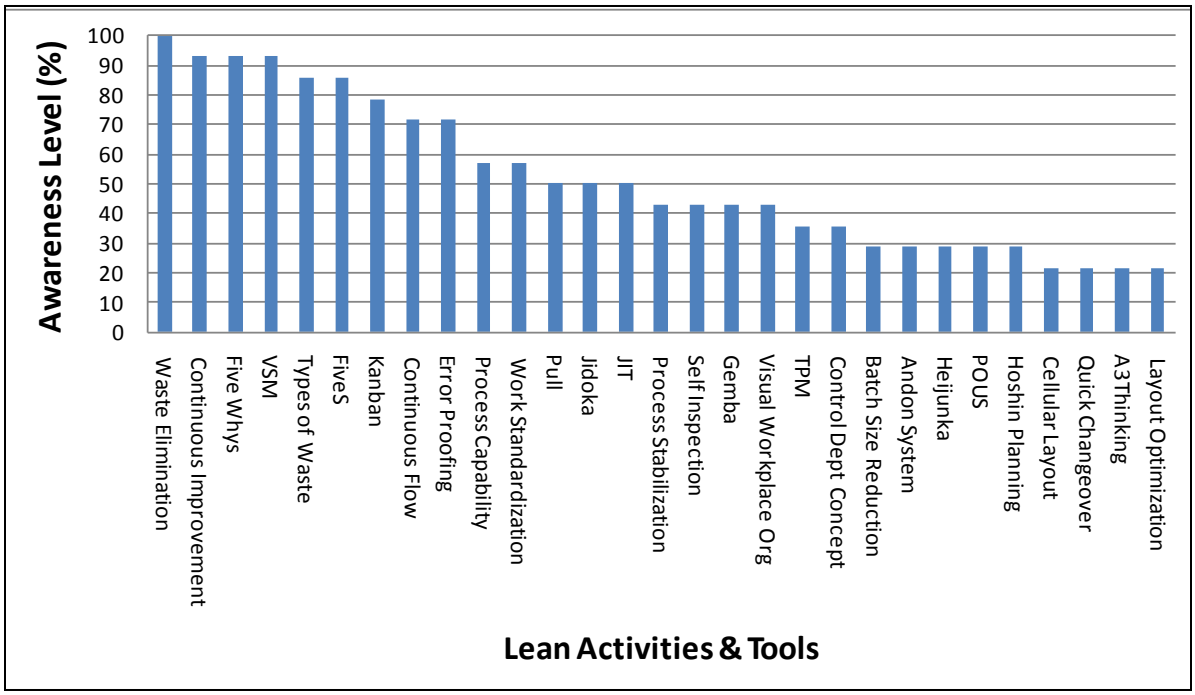


Figure 4.13 Staff awareness level of lean activities and tools

Now that the hospital's accreditation, level of intervention with lean and other quality improvement initiatives, and level of awareness about various lean activities and tools have been illustrated, the remaining part of this section shows how the developed framework provides a quantitative investigation about the current level of adopting various characteristics of sustainable lean implementation in the analyzed hospital.

According to the received responses and based on the data analysis technique presented earlier in chapter 3, the surveyed hospital is located in the lower left corner of the Making Progress zone of the LSAS, Figure 4.14, with 0.58 process factors score and 0.65 organizational factors score. These levels are determined according to the level of staff members' agreement about the status of adopting lean characteristics that lead to sustainable lean implementation

within their hospital. Being located in this zone of the LSAS shows the significant commitment the hospital has to progress towards achieving sustainable levels of lean implementation. Nonetheless, as shown in Figures 4.15 and 4.16, the hospital has potential opportunities for improvement since some of the essential characteristics of such implementation are less adopted and needs to be reinforced. Figure 4.15 shows the hospital's adoption status of these characteristics classified by various LSAT components while Figure 4.16 is a detailed illustration of the adoption status of all lean characteristics stated under each LSAT component. In addition, this figure shows the level of dispersion observed in the reported lean characteristics levels of adoption throughout the whole hospital.

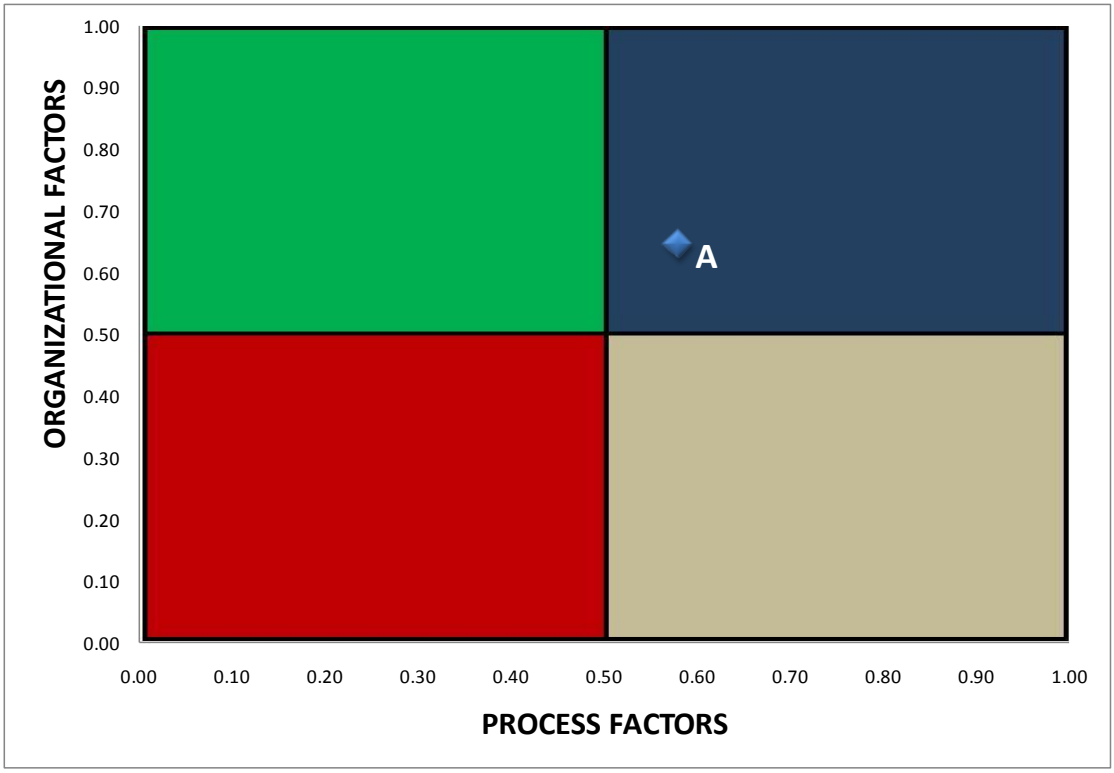


Figure 4.14 The LSAS of hospital A

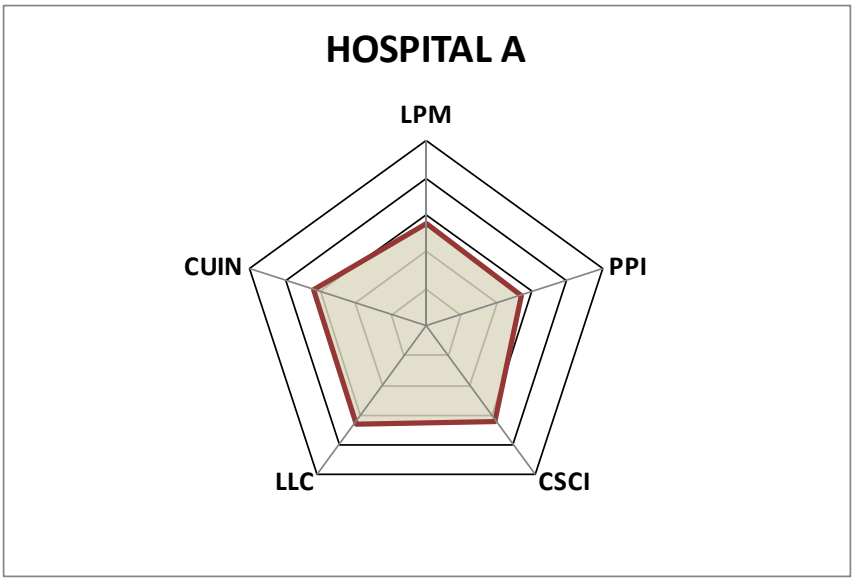


Figure 4.15 The LSAT radar chart of hospital A

From Figure 4.15, it can be inferred that lean characteristics related to various LSAT components are equally implemented with a 0.6 score. When looking at Figure 4.16, it can be seen that the level of implementing characteristics related to lean process maturity (LPM) varies from 40% to less than 80% with LPM3, LPM7, LPM10, and LPM14 as the least adopted characteristics and LPM16, and LPM18 as the most adopted ones. These characteristics are:

- LPM3: defining both start and end points of all processes within various hospital departments,
- LPM7: defining the duration of conducting process steps of all processes within various hospital department,
- LPM10: eliminating process frequent interruption due to unplanned equipment maintenance,

- LPM14: ensuring the availability of process standards in a simple clear format that visually illustrates desired process performance conditions,
- LPM16: designing and updating staff trainings based on the standards developed in the hospital/ department, and
- LPM18: following a scientific-based improvement methodology (e.g., PDCA: Plan-Do-Check-Act) when changing process standards of various hospital processes.

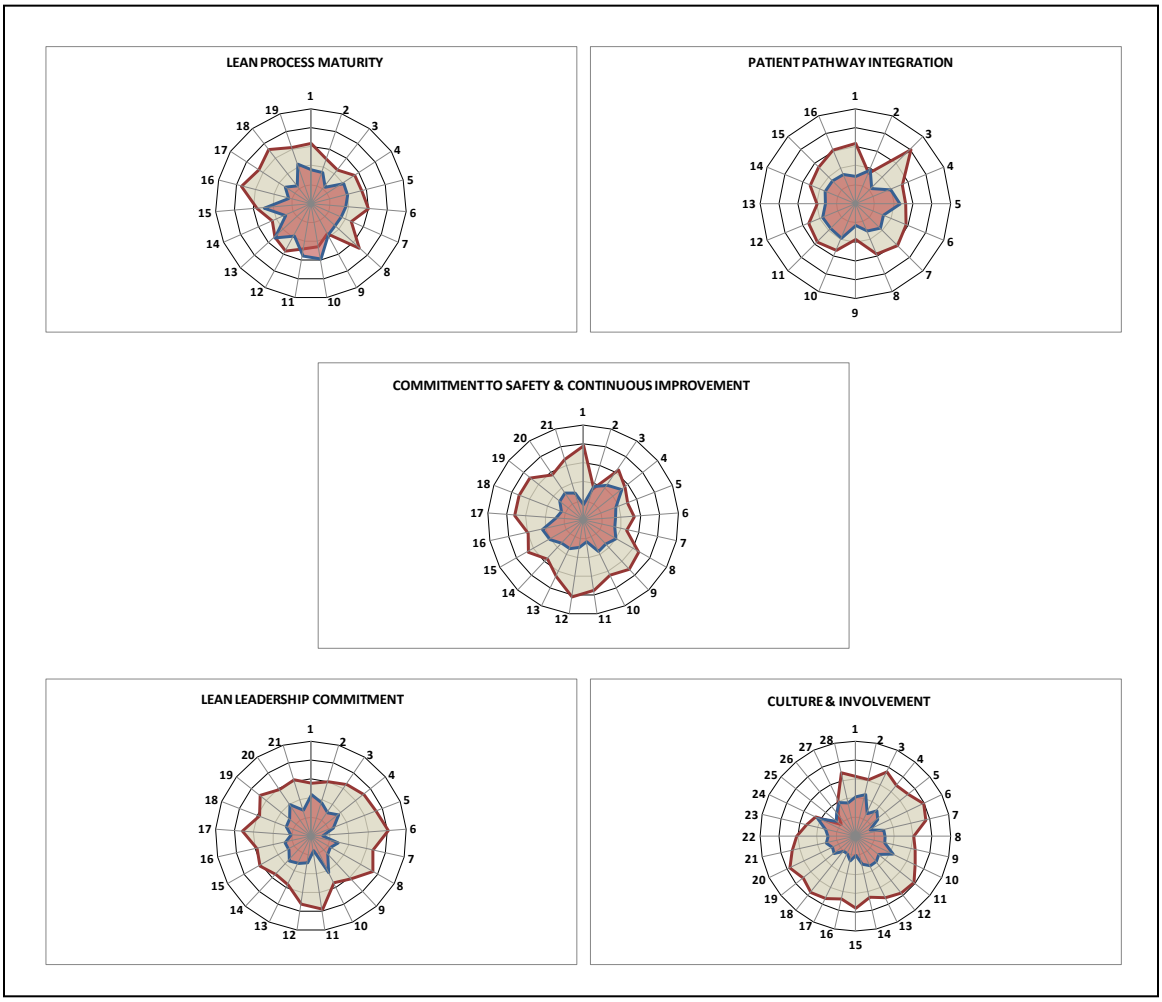


Figure 4.16 The LSAT radar chart of hospital A individual survey components

In addition, Figure 4.16 shows that lean characteristics related to patient/ specimens pathway integration (PPI) are implemented with a level close to 60 % except for PPI2, PPI9, and PPI13, which do not exceed 40% and PPI3, which reaches 80%. These characteristics are:

- PPI2: ensuring the frequent leveling of the department workload to smooth out drastic demand fluctuation in offered healthcare services,
- PPI9: synchronizing all consecutive processes in department pathway(s) to eliminate delays in tasks performed on patients/ specimens,
- PPI13: synchronizing consecutive patient/ specimen pathways within the hospital to eliminate delays in tasks performed on patients/ specimens, and
- PPI3: improving manpower utilization through developing department members' multitasking skills.

Moreover, Figure 4.16 illustrates an almost 60% level of implementation of lean characteristics of the commitment to safety and continuous improvement (CSCI) component of the LSAT except for those related to CSCI17, CSCI18, CSCI19, CSCI1 and CSCI12, which range from 75% to 80%, and CSCI2, which does not exceed 40%. These characteristics are:

- CSCI17: establishing a clear direct link between all continuous improvement efforts conducted at various hospital departments and the advancement of one or more of the hospital's strategic objectives,
- CSCI18: establishing clear definitions about the expected outcomes of all continuous improvement efforts conducted within various hospital departments,
- CSCI19: ensuring the availability of expert guidance while conducting all continuous improvement efforts within various hospital departments,

- CSCI1: maintaining an adequate level of hospital executives support for conducting continuous improvement initiatives throughout the whole hospital,
- CSCI12: having adequate knowledge about the line of support of the department staff in case of having out of control processes, and
- CSCI2: establishing hospital executives' daily gemba walk (i.e. walking through patient/ specimen pathway(s**)** within the whole hospital to identify new areas for improvement),

In regards to those characteristics related to lean leadership commitment (LLC) component of the LSAT, Figure 4.16 shows a range of adoption levels between 60% and 80% with LLC6, LLC8, LLC11, LLC12, and LLC17 as those characteristics which are highly adopted. These characteristics are:

- LLC6: establishing patient-centered hospital strategic objectives with clear goals related to reducing the cost of various hospital processes,
- LLC8: establishing patient-centered hospital strategic objectives with clear goals related to advancing the safety level of various hospital processes,
- LLC11: establishing measures to reflect, in hospital executive level, the performance of the entire hospital towards achieving hospital strategic objectives,
- LLC12: establishing measures, in department management level, to reflect the performance of each department towards achieving hospital strategic objectives, and
- LLC17: setting up the right level of urgency to perceive departmental goals and objectives as challenging but achievable.

Likewise, lean characteristics of culture and involvement (CUIN) component of the assessment tool have a level of adoption ranges from 60% to 80% except for CUIN24 (<50%), CUIN27 (around 40%), CUIN26 (30%), and CUIN25 (20%). These characteristics are:

- CUIN24: establishing a clear performance-based reward and recognition program to value staff participation in process continuous improvement,
- CUIN27: retaining hospital employees by redeploying released staff, due to improving manpower utilization within a process, to other value adding processes in the hospital,
- CUIN26: rewarding hospital staff members based on their number of continuous improvement events attended annually, and
- CUIN25: rewarding hospital staff members based on their number of continuous improvement suggestions submitted annually.

This was a demonstration of how the developed framework could be applied to quantify the sustainability of lean implementation in hospital A. It showed both well adopted and least implemented characteristics which are common to all hospital departments. However, recommendations about what to do to move towards higher levels of sustainability should not be made prior to investigating the level of hospital staff members' agreement about the observed scores of the evaluated factors. Such investigation, which is done by using the Dissension (Dnt) measure, might reveal the necessity of conducting further analysis on department level and providing department-specific recommendations to each department of the analyzed hospital.

By looking at the level of dispersion observed in the reported lean characteristics levels of adoption in hospital A, Figure 4.16, a separate analysis needs to be conducted for each

department in order to determine department-specific sets of recommendations. This is because the observed level of dispersion is more than 20% (i.e. outside the inner circle of the radar chart) for most of the lean characteristics of the LSAT components. However, before proceeding with the analysis of individual departments of hospital A, the adoption level of lean sustainability characteristics in its various department types must be explored.

Figure 4.17 shows that the survey responding departments are classified into:

- Clinical services departments (38%),
- Nonclinical services departments (54%), and
- Ancillary services department (8%).

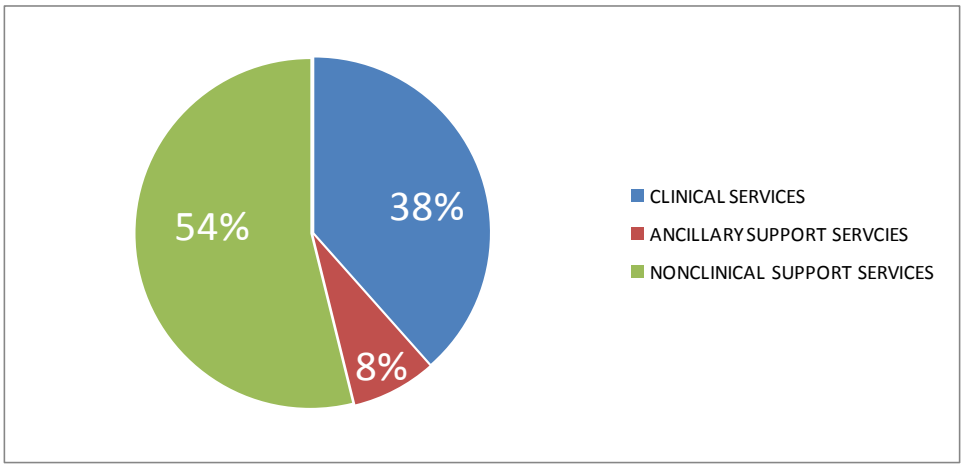


Figure 4.17 Types of responding departments of hospital A

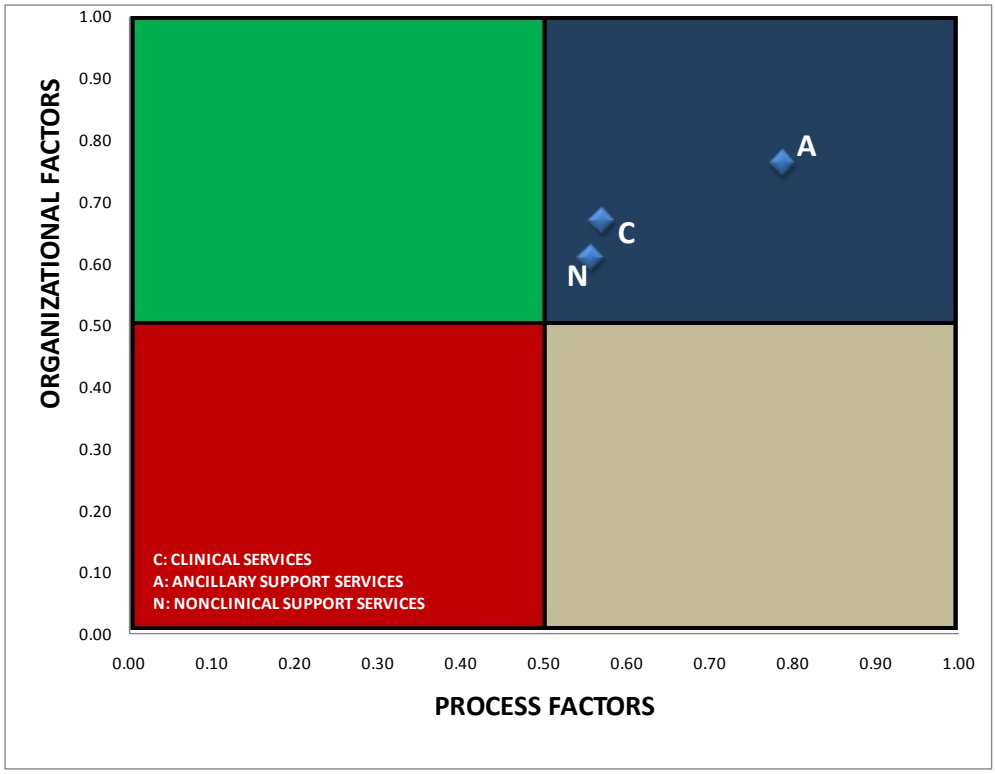


Figure 4.18 The LSAS of department types of hospital A

Factors scores of all these department classes locate them in the Making Progress zone as presented in Figure 4.18. However, the figure shows that the level of adopting lean sustainability characteristics in the ancillary services departments supersedes the adoption level of these characteristics in the other two classes. This, also, can be concluded by looking at Figure 4.19 which presents the LSAT radar chart of department types of the hospital. In addition, as in Figure 4.20, the level of dispersion observed in most of the reported lean characteristics levels of adoption within two of the department classes is more than 20% (i.e. outside the inner circle of the radar chart). This confirms the need of performing the analysis on department level prior to provide any improvement recommendations. Such analysis starts by constructing the LSAS of all surveyed departments based on the calculated factors scores.

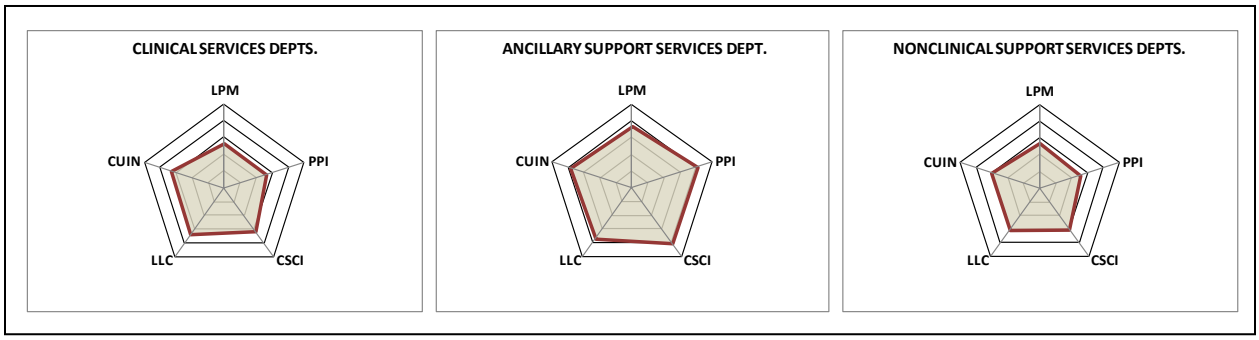


Figure 4.19 LSAT radar chart of department types of hospital A

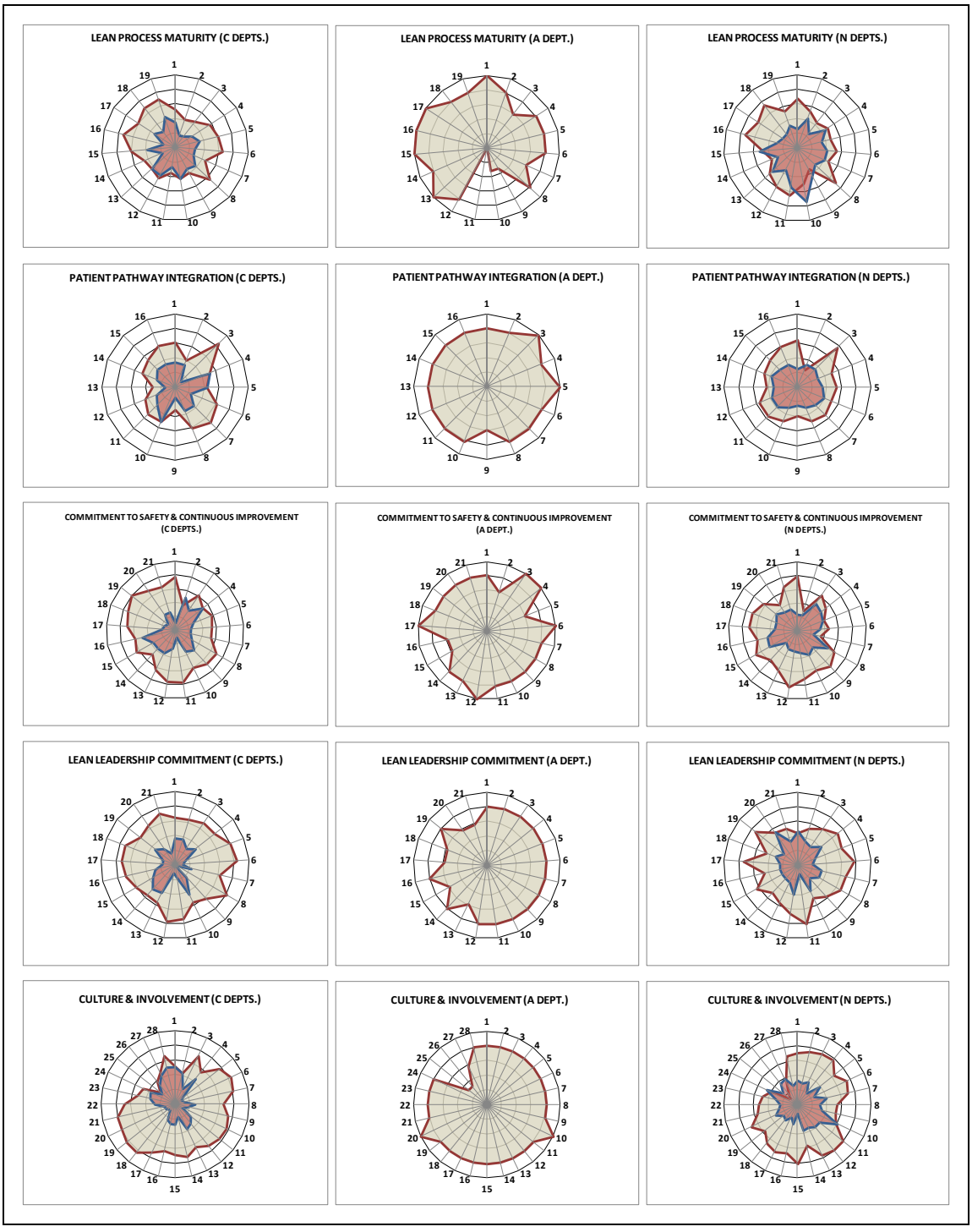


Figure 4.20 The LSAT radar chart of individual survey components of department types of hospital A

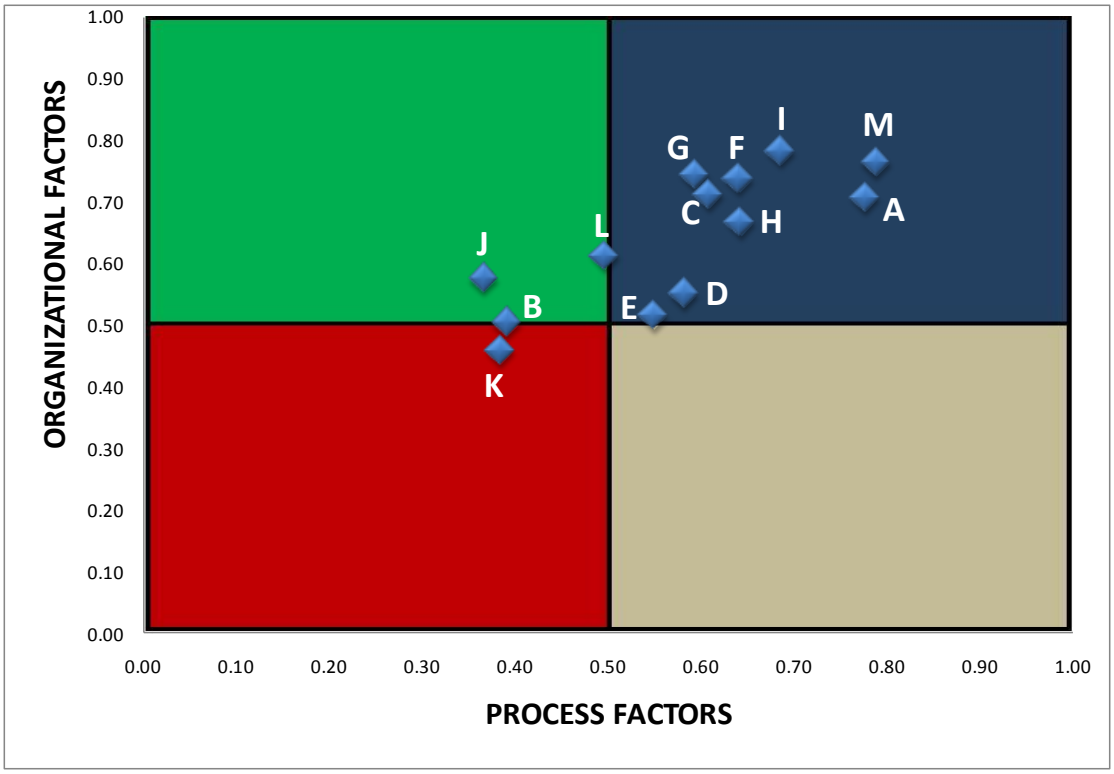


Figure 4.21 The LSAS of hospital A participating departments

According to the factors scores shown in Figure 4.21, nine of the surveyed hospital departments are located in the Making Progress zone, three in the Commencing zone, and one in the critical zone of the LSAS. Among those departments in the Making Progress zone, departments M and E have the highest and the lowest observed scores respectively. Other departments in this zone have different combinations of process factors and organizational factors scores between the scores of these two departments. However, the range of variation of both factors scores is nearly identical (i.e. between 0.5 and 0.8).

When comparing those departments which are spread over the Commencing zone, it can be seen that department L has the highest level of both factors adoption while departments J and

B supersede each other in the level of adopting one of the factors' groups. Figure 4.21 also shows that department K is located in the Crtical zone with a nearly 0.4 process factors score and 0.45 organizational factors score.

Another way to analyze the status of implementing these factors within the surveyed departments of hospital A is by comparing their LSAT radar charts which are presented in Figure 4.22 below. From these charts, it can be inferred that departments M and K have, respectively, the highest and the lowest levels of factors adoption. In addition, the figure shows the immense deviation of department J in adopting the patient pathway integration (PPI) component of the process factors as compared to other departments. Moreover, the figure shows that departments J, K, L, and B are expected to spend more efforts as well as get more attention from hospital executives in order to achieve such targeted levels of factors adoption as 80% or more. Furthermore, charts presented in this figure provide a valuable benchmarking information about those departments with high adoption levels of some of the components of the developed LSAT. Lean practices within these departments should be analyzed in order to be applied throughout the whole hospital.

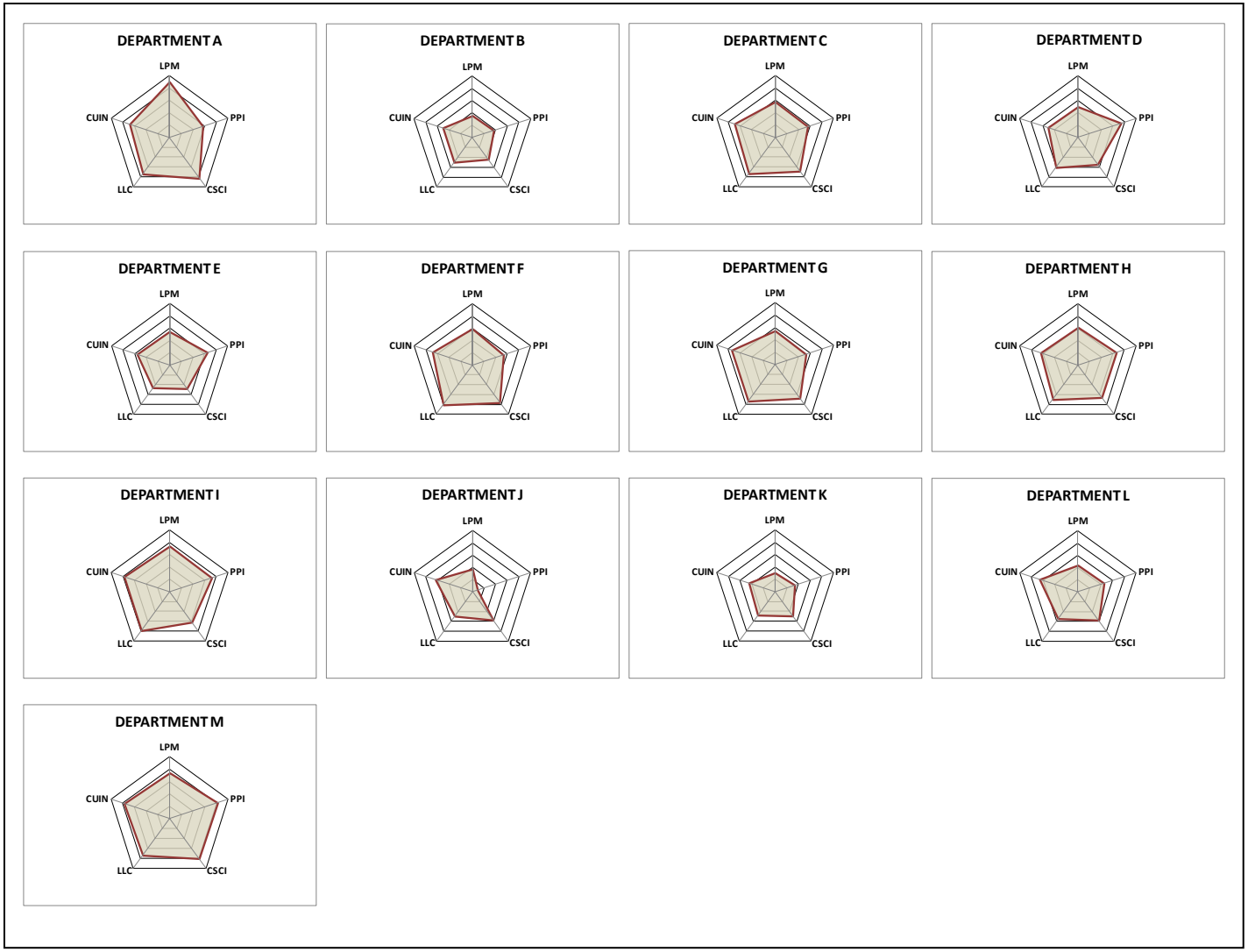


Figure 4.22 The LSAT radar chart of departments at hospital A

A more detailed view about the status of implementing various lean characteristics under each component of the LSAT is presented in Figures 4.23 through 4.27. Based on the observed level of adopting these characteristics within hospital departments, various sets of department-specific recommendations reports must be generated. As an illustration, Table 4.4 presents the recommendation report for department A of the surveyed hospital. This report is composed of the desired conditions of various lean characteristics included in the LSAT together with their current level of implementation, in both department level and hospital level, coded in colors and icons format presented earlier in Table 4.1. As shown in that table and in order to achive higher levels of lean sustainability, the developed action plan should address the red coded characteristics first since they are the least adopted and need an immediate attention according to the current observed levels of lean implementation.

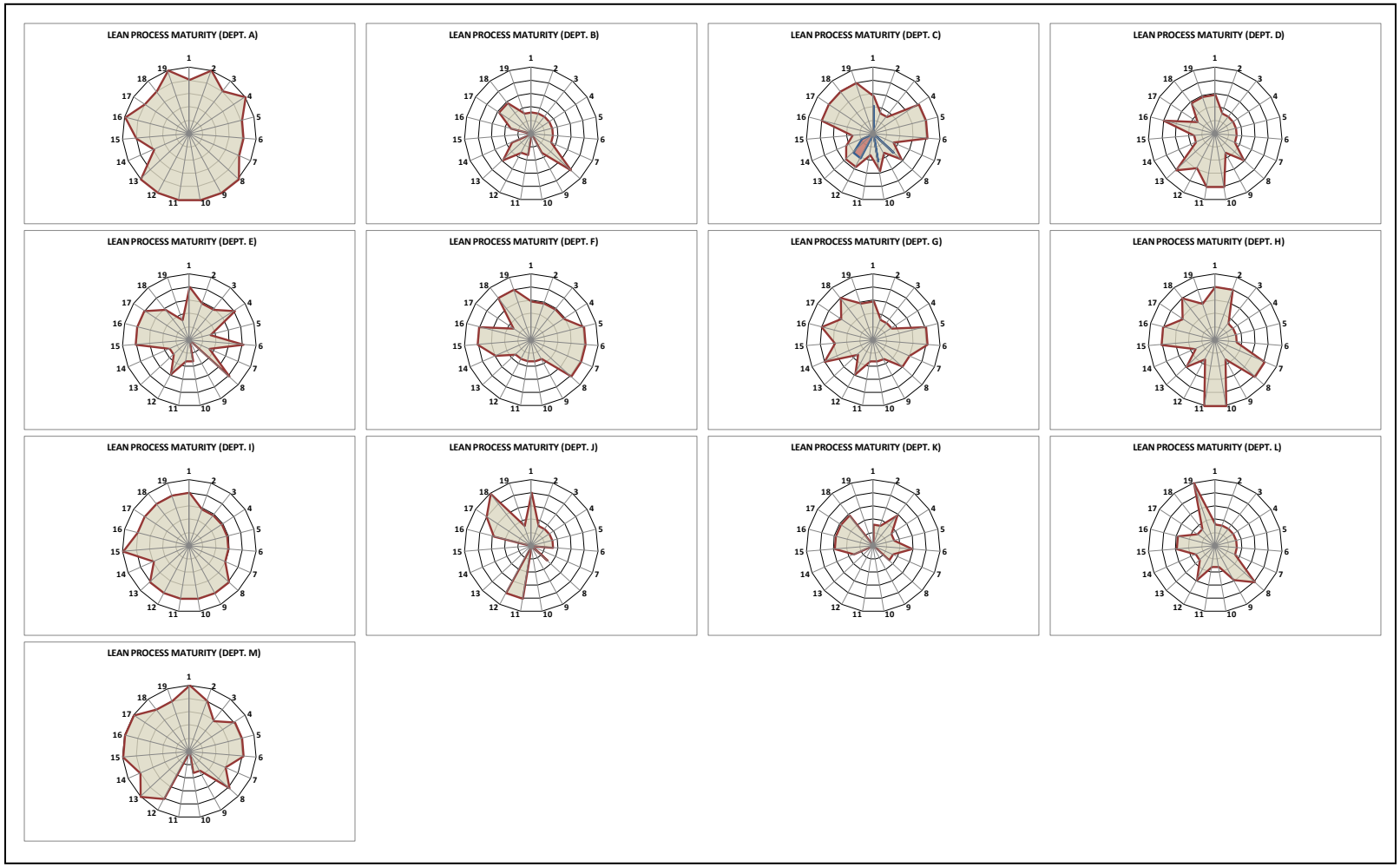


Figure 4.23 The radar chart of LPM characteristics of all departments of hospital A

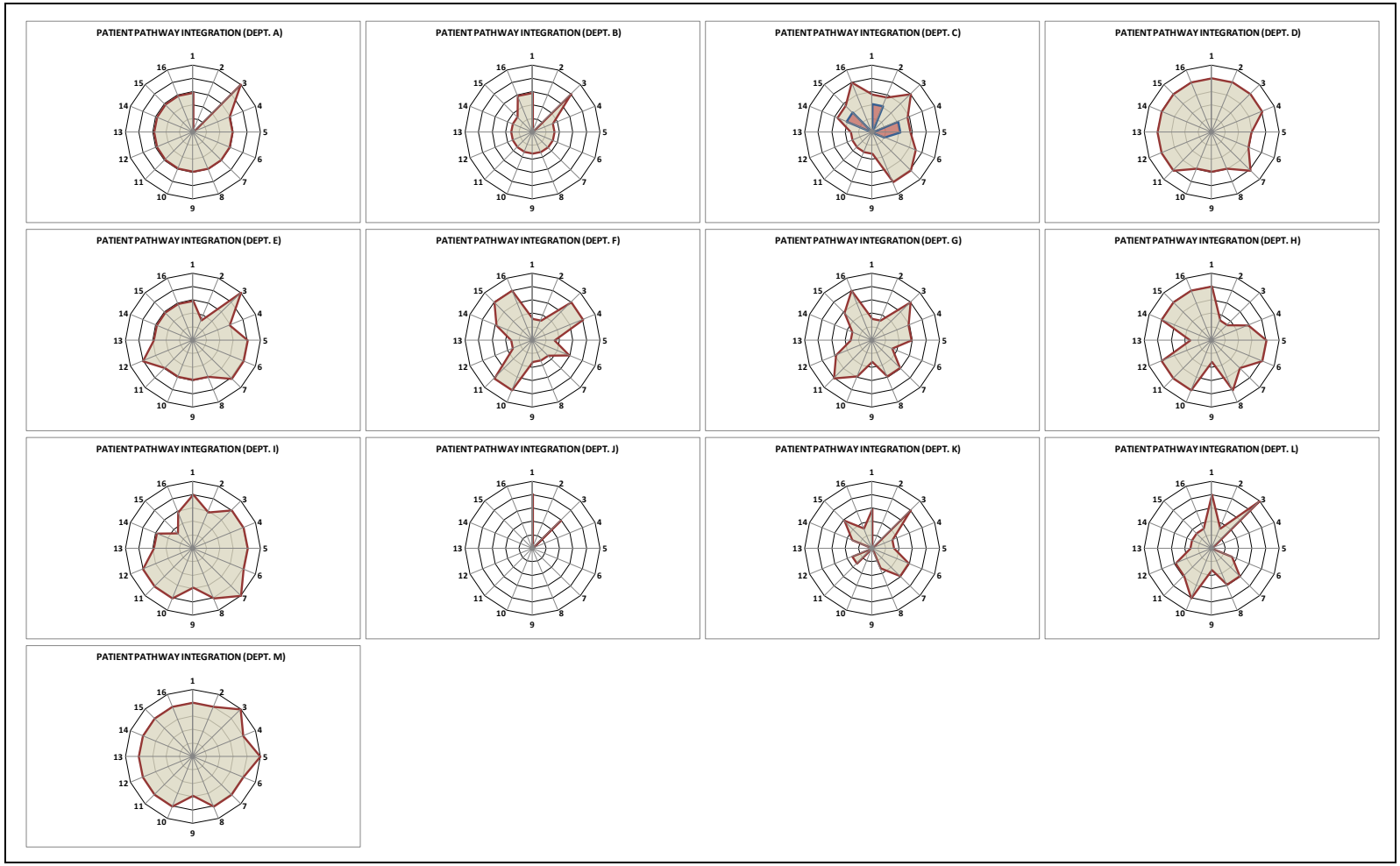


Figure 4.24 The radar chart of PPI characteristics of all departments of hospital A

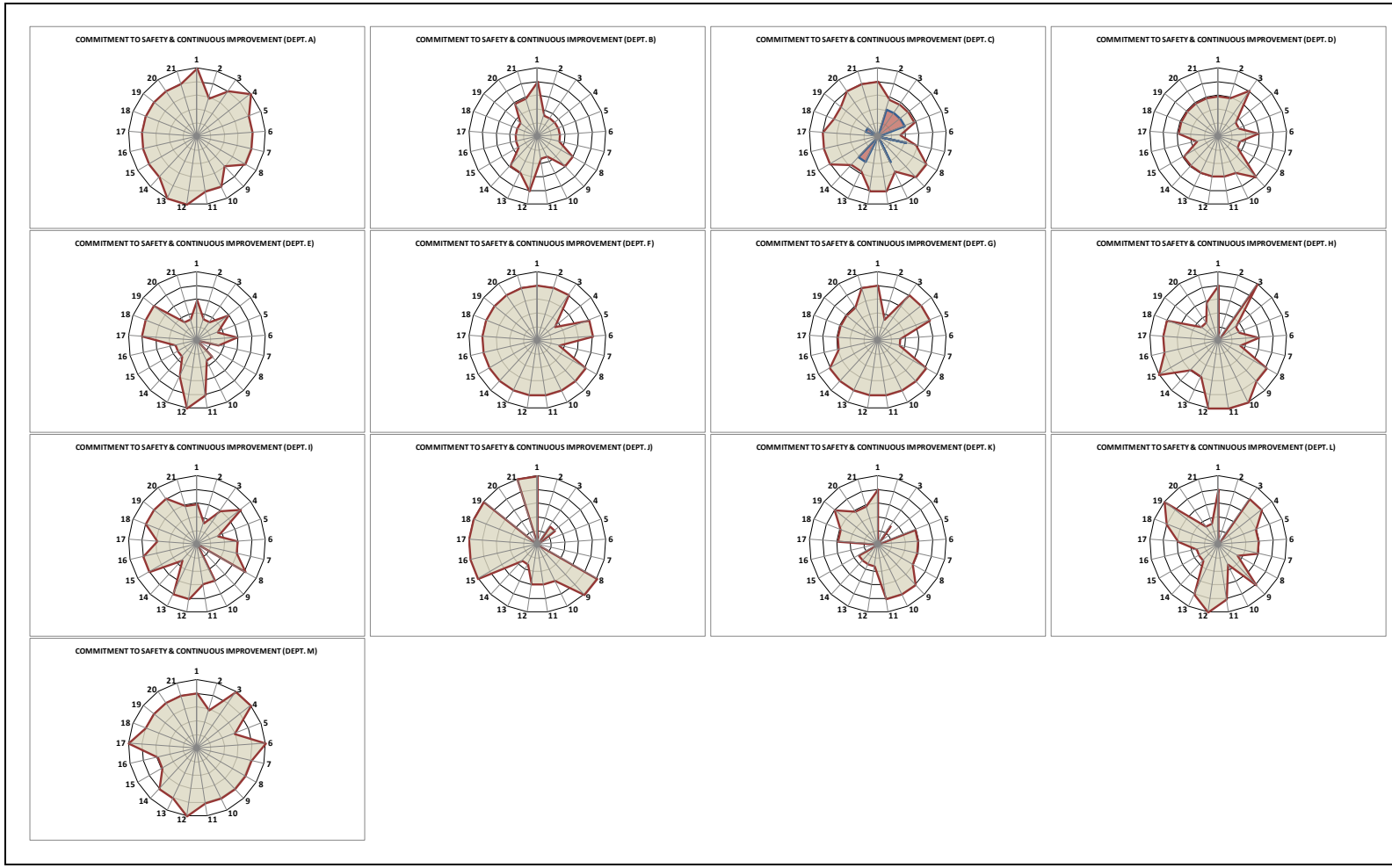


Figure 4.25 The radar chart of CSCI characteristics of all departments of hospital A

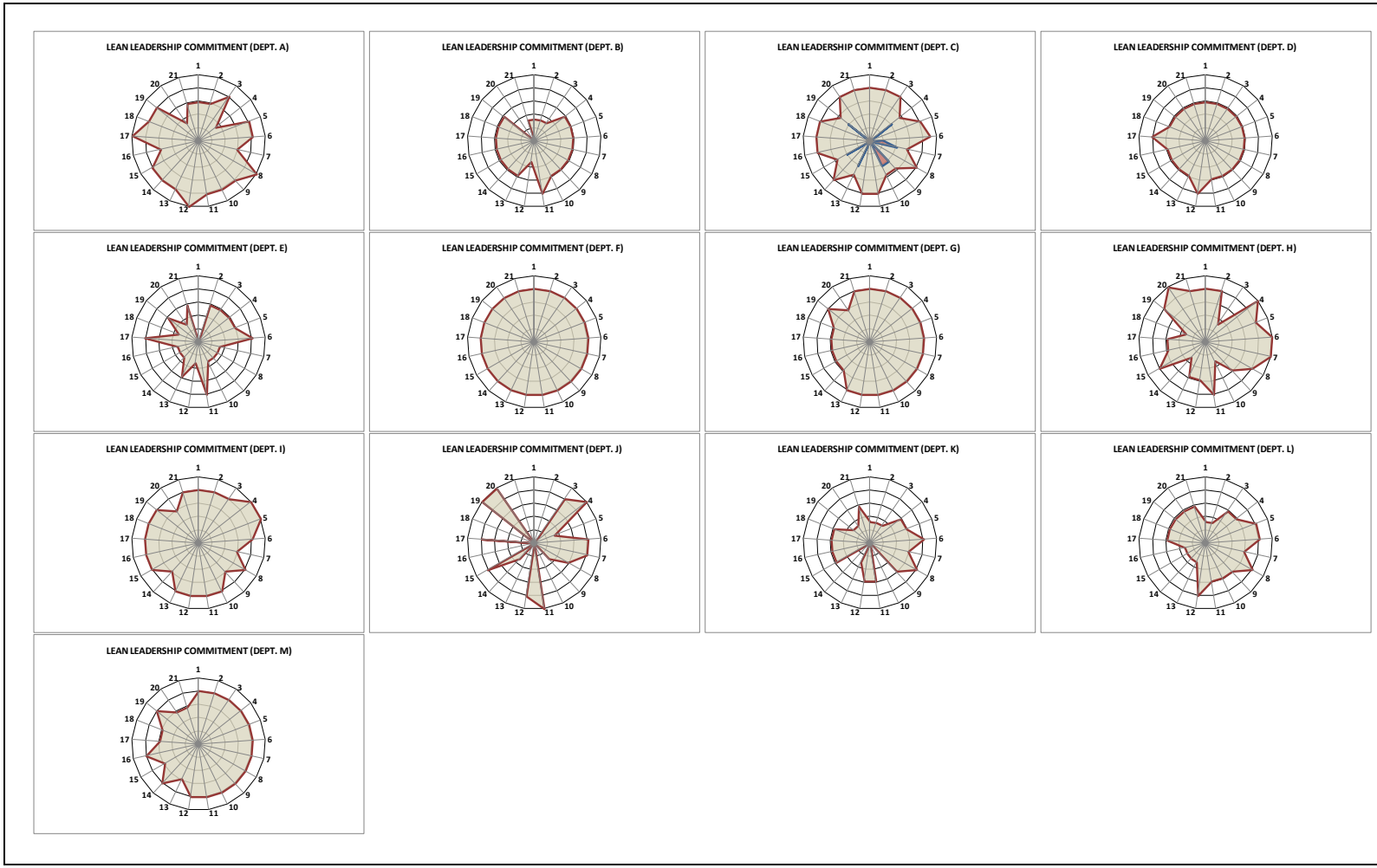


Figure 4.26 The radar chart of LLC characteristics of all departments of hospital A

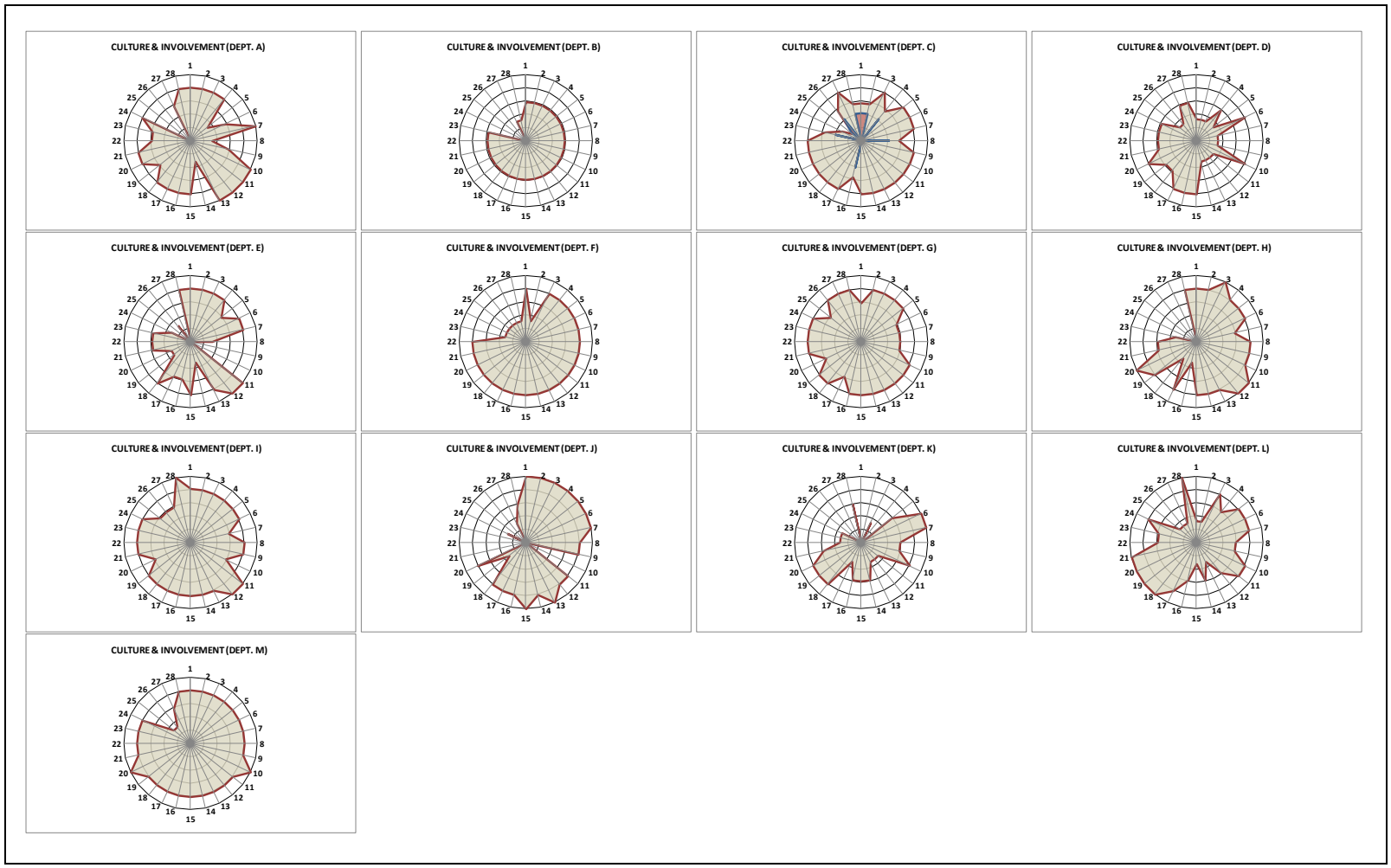


Figure 4.27 The radar chart of CUIN characteristics of all departments of hospital A

Table 4.4 Department A recommendations report

Dept. (A)	Hospital (A)	Question Code	Factors Measured	Desired Conditions
●	◕	LPM1	Process Stability	Give a designated name to each process in each department.
●	◑	LPM2		For all processes in each department, assign a process owner(s) to be in-charge of conducting process training and assuring conformance to process performance standards.
●	◑	LPM3		Define clearly both start and end points of each process in each department.
●	◑	LPM4		Define clearly the outcomes of each process in each department.
●	◑	LPM5		Define clearly the steps of each process in each department.
●	◕	LPM6		Define clearly the sequence of process steps of each process in each department.
●	◑	LPM7		Define clearly, the duration of process steps of each process in each department.
●	◕	LPM8		Enroll hospital staff members in training sessions related to their process(es) to maintain the competence level needed to achieve defined process outcomes.
●	◔	LPM9		Review staff scheduling for each process in each department to confirm the availability of the minimum number needed to achieve the defined process outcomes.
●	◑	LPM10		Develop a schedule for conducting maintenance activities on all equipment utilized within each department . Whenever possible, shift some tasks of these activities from the maintenance team to the frontline staff.
●	◑	LPM11		Review the amount of supplies related to each process in each department and define stock levels suitable to trigger the replenishment process of each item.
●	◑	LPM12		Ensure the availability of process performing instructions at the point where process tasks are conducted.
●	◑	LPM13		Ensure that all equipment, tools, and supplies needed to conducted each process in each department are either labeled or stored in designated labeled compartments. Arrange these items within the process operating area in a way that optimizes process operation.
◑	◑	LPM14	Process Standardization	Provide a visual illustration of process performance conditions by presenting their related instructions in a drawing or picture format.
●	◑	LPM15		Develop a mechanism to capture the Tacit knowledge of hospital staff members in order to be included when developing newer versions of process performance standards.
●	◕	LPM16		Design and update staff trainings according to the newly developed process performance standards applied at each department.
●	◕	LPM17		Develop new process standards or update the existing ones as soon as new forms of waste (i.e. non-value adding activities) are identified.
●	◕	LPM18		Follow a scientific-based improvement methodology (e.g. PDCA: Plan-Do-Check-Act) when developing/ updating standards of a process.

Dept. (A)	Hospital (A)	Question Code	Factors Measured	Desired Conditions
●	◕	LPM19	**Process Standardization**	Target increasing staff utilization prior to target increasing equipment utilization when developing/ updating standards of a process.
◑	◕	PPI1	**Patient Flow Streamlining**	Ensure the availability of resources (i.e. staff, supplies, data, and equipment) required to deliver a patient's defined value at the patient's point of care.
○	◔	PPI2		Improve departments' response to drastic demand fluctuation in offered services through frequent adjustment of the workload level of each department.
●	●	PPI3		Develop the multitasking skills of department members, on continuous-basis, in order to respond to fluctuation in department workload and improve manpower utilization.
◑	◑	PPI4		Arrange various processes within each department to form a pathway sequenced according to a convenient patient/ specimen flow within the whole department.
◑	◑	PPI5		Ensure that all consecutive processes within each department patient/ specimen pathway(s) are directly connected.
◑	◑	PPI6		Ensure that all consecutive processes within each department patient/ specimen pathway(s) are linked based on a supplier-customer relationship.
◑	◕	PPI7		Ensure that all processes within each department patient/ specimen pathway(s) are directly connected to their internal and external suppliers.
◑	◑	PPI8		Establish a clear signaling mechanism between processes of each department and their suppliers so they can send requests and receive responses about resource requirements needed for delivering patient defined values.
◑	◔	PPI9		Synchronize all consecutive processes in each department pathway(s) to eliminate delays in tasks performed on patients/ Specimens.
◑	◑	PPI10		For all patient/ specimen pathways in each department, assign a pathway owner(s) to be in-charge of assessing the way of performing related task and assuring conformance to pathway performance standards.
◑	◑	PPI11		Ensure that Patient/ specimen pathway(s) within each department have a clearly defined start and end points at which they interface with other pathways in the hospital.
◑	◑	PPI12		Develop new department patient/ specimen pathway standards or update the existing ones as soon as new forms of waste (i.e. non-value adding activities) are identified.
◑	◑	PPI13		Coordinate with other hospital departments to ensure synchronization of patient/ specimen pathway(s) throughout the hospital.
◑	◑	PPI14		Coordinate with other hospital departments to develop new hospital patient/ specimen pathway standards or update the existing ones as soon as new forms of waste (i.e. non-value adding activities) are identified.

Dept. (A)	Hospital (A)	Question Code	Factors Measured	Desired Conditions
◑	◑	PPI15	**Patient Flow Streamlining**	Coordinate with other hospital departments to develop the integrated main pathways of the whole hospital.
◑	◕	PPI16		Coordinate with other hospital departments to ensure that main hospital pathways are formed based on patient's defined values.
●	◕	CSCI1	**Continuous Improvement**	Engage hospital executives with various activities of continuous improvement initiatives conducted in the whole hospital throughout projects' sponsoring and support.
◑	◔	CSCI2		Engage hospital executives with a daily walk through different patient/specimen pathways within the whole hospital to identify new areas for improvement.
●	◕	CSCI3		Engage department managers with a daily walk through different patient/specimen pathways within their departments to identify new areas for improvement.
●	◑	CSCI4	**Mistake Proofing**	At each department, develop a simple comprehensive information display system through which department members can share the knowledge about the overall performance of their department.
●	◑	CSCI5		Throughout the hospital, develop a simple comprehensive information display system through which hospital staff members can share the knowledge about the overall performance of the entire hospital.
●	◑	CSCI6		Incorporate an inspection mechanism within the standards of each process in your department in order to inspect each process outcome(s) prior to proceeding to the next process (es).
●	◑	CSCI7		Establish a feedback mechanism among all consecutive processes in your department to contain errors/ defects prior to have them spread into other hospital departments.
●	◕	CSCI8		Encourage all hospital members to stop any process within the whole hospital and interrupt patient/ specimen pathway(s) upon observing the occurrence of an error or defect related to process desired outcomes.
◑	◕	CSCI9		Encourage all hospital members to stop any process within the whole hospital and interrupt patient/ specimen pathway(s) upon observing the occurrence of an error or defect related to patient safety.
●	◕	CSCI10		Establish multidisciplinary teams to respond to process errors detected in the hospital in order to trace them to their ultimate root cause(s). These team must be made of all stakeholders in relation with affected process(es) .
●	◕	CSCI11		Establish multidisciplinary teams to respond to safety incidents reported in the hospital in order to trace them to their ultimate root cause(s). These team must be made of all stakeholders in relation with incidents' causing process(es).
●	●	CSCI12		Educate hospital members about their line of support (i.e. supervisors and/or managers) whom they should contact when their process(es) go out of control.
●	◕	CSCI13		Establish a clear signaling mechanism that help hospital members convey their support requests to their line of support in a direct manner.

Dept. (A)	Hospital (A)	Question Code	Factors Measured	Desired Conditions
●	◑	CSCI14	**Mistake Proofing**	Establish a standard procedure for handling support related requests (i.e. response time, team members who should attend within each hospital zone, and any other alternative plans if needed) for each process within the entire hospital.
●	◕	CSCI15	**Continuous Improvement**	Educate hospital members to follow a scientific-based improvement methodology (e.g. PDCA: Plan-Do-Check-Act) when conducting any continuous improvement related efforts within their departments.
●	◑	CSCI16		Train all hospital members on the continuous improvement method adopted by the hospital.
●	◕	CSCI17		Ensure that all continuous improvement efforts performed by hospital members are made to advance one or more of the hospital's strategic objectives.
●	◕	CSCI18		Ensure that all continuous improvement efforts performed by hospital members have clearly expected outcomes.
●	◕	CSCI19		Ensure that all continuous improvement efforts performed by hospital members are conducted under the guidance of a teacher (i.e. a process owner).
●	◑	CSCI20		Establish a suggestion program through which continuous improvement ideas flow from staff towards hospital management.
●	◕	CSCI21		Establish a mechanism that regularly updates hospital management with the results of continuous improvement efforts conducted by staff members.
◑	◑	LLC1	**Leadership**	Hospital executives should establish a clear vision about the meaning of "process perfection" and has it shared with all staff members.
◑	◑	LLC2		Hospital executives should establish a clear vision about "what constitutes patient's needs" and has it shared with all staff members .
●	◕	LLC3		Develop hospital strategic objectives based on patients' defined needs (i.e. values).
◔	◕	LLC4		Develop patient-centered hospital strategic objectives with clear goals related to advancing the productivity level of hospital processes.
●	◕	LLC5		Develop patient-centered hospital strategic objectives with clear goals related to advancing the quality level of hospital processes.
●	●	LLC6		Develop patient-centered hospital strategic objectives with clear goals related to reducing the cost of hospital processes.
◑	◕	LLC7		Develop patient-centered hospital strategic objectives with clear goals related to reducing both lead and processing time of hospital processes.
●	◕	LLC8		Develop patient-centered hospital strategic objectives with clear goals related to advancing the safety level of hospital processes.

Dept. (A)	Hospital (A)	Question Code	Factors Measured	Desired Conditions
●	◕	LLC9	Leadership	Develop patient-centered hospital strategic objectives with clear goals related to improving the environmental setup of hospital processes.
●	◑	LLC10		Develop patient-centered hospital strategic objectives with clear goals related to improving the morale level of hospital staff, patients, and suppliers.
●	◕	LLC11		Hospital executives should establish measures to reflect the performance of the entire hospital towards achieving hospital strategic objectives.
●	◕	LLC12		Department managers should establish measures to reflect the performance of their departments towards achieving hospital strategic objectives.
●	◑	LLC13		Establish a mechanism to measure advancement towards fulfilling hospital strategic objectives on a daily basis.
●	◑	LLC14		Establish a mechanism that enhances the awareness of all department members about hospital strategic objectives.
●	◕	LLC15		Ensure that the developed hospital strategic goals are challenging enough to convey the right level of urgency needed to motivate for endless improvement cycles towards perfection.
◑	◑	LLC16		Establish a mechanism to transform hospital strategic objectives into actionable plans for each department in the hospital.
●	◕	LLC17		Ensure that the developed departmental actionable plans have goals and objectives challenging enough to convey the right level of urgency needed to motivate for endless improvement cycles towards perfection.
●	◑	LLC18		Establish a mechanism to transform hospital strategic objectives into specific responsibilities and performance targets for each staff member in the hospital.
●	◕	LLC19		Enforce the "Control Department Concept" among various hospital departments (i.e. each department is accountable for coordinating the efforts of different departments involved in achieving cross-functional goals which falls under its specific plan for achieving the hospital's strategic objectives).
◔	◑	LLC20		Establish a mechanism to encourage hospital departments to consider supporting the cross- functional goals of other departments when developing the plan of their own departments.
◑	◕	LLC21		Hospital executives should incorporate plans of all departments into one master plan to assure their alignment towards achieving defined strategic objectives.
●	◕	CUIN1	Culture & Involvement	Establish educational activities and arrange regular departmental events to promote, among hospital staff members, the understanding of Lean as a business philosophy which creates value through creating trust and fulfillment.
●	◕	CUIN2		Establish educational activities and arrange regular departmental events to promote, among hospital staff members, the understanding of Lean as more than waste elimination and cost reduction.

Dept. (A)	Hospital (A)	Question Code	Factors Measured	Desired Conditions
		CUIN3	Culture & Involvement	Establish educational activities and arrange regular departmental events to promote, among hospital staff members, the realization of continuous improvement initiatives as efforts conducted to attack problems and processes not people.
		CUIN4		Establish educational activities and arrange regular departmental events to promote, among hospital staff members, the realization of process continuous improvement as a way of work and not just a quality initiative.
		CUIN5		Establish educational activities and arrange regular departmental events to promote, among hospital staff members, that process redesign should be based on patient's defined needs.
		CUIN6		Conduct basic and refreshing training sessions, regular quality circle discussions, and encourage participation in continuous improvement events to enhance hospital members capabilities of identifying patient needs and developing countermeasures or solutions required to fulfill them.
		CUIN7		Conduct basic and refreshing training sessions, regular quality circle discussions, and encourage participation in continuous improvement events to enhance hospital members capabilities of identifying different types of waste which constitutes non-value adding activities within their processes.
		CUIN8		Ensure that Lean training sessions are properly structured to progressively improve department members' understanding about various Lean activities and tools and how they can be applied to their daily performed activities.
		CUIN9		Encourage department members to continuously participate in improvement projects related to their processes.
		CUIN10	Respect for Employees	Develop a mechanism to ensure the engagement of hospital staff members with simultaneous doing and learning infinite cycles in order to enhance their Lean leadership skills.
		CUIN11		Encourage hospital members to develop and improve standards related to their processes.
		CUIN12		Encourage hospital members to utilize their creativity to gradually improve their processes prior to jumping to capital investment solutions.
		CUIN13		Enforce the accountability of hospital members for conducting continuous improvement initiatives to solve specific problems related to their processes.
		CUIN14	Culture & Involvement	Establish a mechanism to ensure the involvement of hospital supervisors, managers, and executives in process improvement activities through providing necessary support to various department members.
		CUIN15		Establish a mechanism to ensure that all problem solving and continuous improvement activities are conducted by multidisciplinary teams made of all stakeholders affected by developed solutions and/ or redesigned process(es).

Dept. (A)	Hospital (A)	Question Code	Factors Measured	Desired Conditions
●	◕	CUIN16	**Respect for Employees**	Establish a mechanism to ensure that all problem solving and continuous improvement teams are formed from frontline hospital staff members (i.e. nurses, technicians, and allied health personnel) with the support of supervisors and managers from all levels of the hospital.
●	◕	CUIN17	**Culture & Involvement**	Establish a mechanism to ensure that all problem solving and continuous improvement teams have at least one member of the hospital executive team as a champion.
●	◕	CUIN18		Encourage establishing the practice of regular meetings of a group of members within each department to identify areas for improvement within the department.
◑	◕	CUIN19		Encourage establishing the practice of regular meetings of a group of hospital staff members from different departments to identify new areas for improvement throughout the whole hospital.
●	◕	CUIN20		Establish a mechanism to ensure that there is at least one representative from each department attending hospital meetings for identifying various areas for improvement.
●	◕	CUIN21	**Respect for Employees**	Establish a suggestion program through which staff members can deliver their ideas for improvement to hospital management.
◑	◕	CUIN22		Ensure that the hospital suggestion program has a mechanism for prioritizing implementation of staff suggestions based on their relevance to hospital strategic objectives.
◑	◑	CUIN23		Ensure that the hospital suggestion program has a mechanism for expediting implementation of staff suggestions, even if they are sub-optimal, based on their relevance to hospital strategic objectives.
●	◑	CUIN24		Establish a clear performance-based reward and recognition program to value staff participation in process continuous improvement activities conducted in the hospital.
○	○	CUIN25		Ensure that department members are rewarded based on the number of continuous improvement suggestions they submit annually.
○	◔	CUIN26		Ensure that department members are rewarded based on the number of continuous improvement events they attend annually.
◑	◑	CUIN27		Establish a mechanism to ensure that hospital staff members released from a process, due to improving manpower utilization, are redeployed to other value adding processes in the hospital.
●	◕	CUIN28		Establish a mechanism to ensure that hospital has training and career advancing policies based on equal skill development opportunities for all hospital staff members.

4.4 Concluding Remarks

In the previous two sections, a demonstration has been made about the developed framework application on a simulated data of group of nine hospitals and on a real data of one of U.S. hospitals in State of Florida. The simulated data in section 4.2 was mainly presented to provide a general overview about the rationale behind the depth of the analysis required to provide a meaningful set of recommendations to the surveyed hospitals. Section 4.3 validated the usability of the developed framework in generating department-specific sets of recommendations based on the collected data of hospital A. In this section, a discussion will be made about some of the aspects related to the observed levels of lean sustainability in that hospital in the content of those information gathered by section one of the LSAT (i.e. status of hospital's A quality management system and quality improvement efforts).

The accreditation history of hospital A reflects the commitment of its members in providing healthcare services with high levels of quality. The nine years of hospital's exposure to six sigma and lean six sigma led to a significantly high level of adoption of the characteristics of sustainable lean implementation. Applying these two quality improvement initiatives on the department level resulted in a recognized cost saving and quality improvement in offered healthcare services. Although the hospital did not implement lean as a management system of the whole hospital, the following approaches, usually adopted by organizations during lean transformation stages, have been observed:

- Recruiting external consultant to guide the organization while applying lean,

- Relying on internal expert(s) to guide the organization through various stages of lean application,
- Providing lean basic training to hospital executives, managers, and supervisors before starting lean application, and
- Starting lean application gradually throughout the organization by first selecting a department or a process where results of lean initiatives can be easily and promptly discerned.

A variation has been observed in received responses to section one of the assessment tool especially when responding to the question about the departments in which lean, six sigma, and lean six sigma have been applied. This variation could be regarded to the different level of involvement each member of the quality management department might have with the conducted projects throughout the hospital.

Due to the fact that the hospital experience with lean is through conducing lean six sigma projects on department level, those lean activities and tools utilized usually in such projects are recognized by 80% or more of the responding managers. These activities and tools are: waste elimination, continuous improvement, five whys, value stream mapping, types of waste, and five S's. However, the remaining 23 lean activities and tools included in the study are known to 20% or more of the responding managers. Among these activities and tools, kanban, continuous flow, error proofing, process capability, work standardization, pull, jidoka, and just-in-time are recognized by at least 50% of the responding managers.

The observed process factors scores and organizational factors scores indicate that characteristics of sustainable lean implementation are variably adopted within various types of

hospital departments. The level of adopting lean sustainability characteristics in the ancillary services departments supersedes the adoption level of these characteristics in both clinical services and nonclinical supports services departments. Based on this and in addition to the observed dispersion levels associated with the reported lean characteristics levels of adoption of the surveyed departments, further analysis ought to be performed on individual department level in order to generate their specific reports of recommendations. One of these reports has been presented at the end of section 4.3. This report is composed of the desired conditions of various lean characteristics included in the LSAT together with their current level of implementation, in both department level and hospital level, coded in colors and icons format presented earlier in Table 4.1. Hospital departments should use this recommendation report in order to move towards enhanced levels of sustainable lean implementation. The department-based suggested action plan should address the red coded characteristics first since they are the least adopted and need an immediate attention. In order to help hospital members read the developed assessment charts and recommendation reports, Figure 4.28 has been developed.

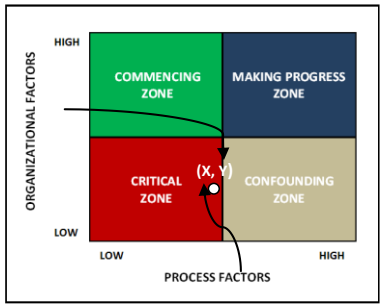
Despite the fact that not all departments of hospital A have participated in the assessment process, the obtained results of this assessment can serve as a base for developing hospital-wide action plans to improve the overall sustainability level of lean implementation. Table 4.5 presents a summarized overview about the conducted assessment of all departments of hospital A. It compares the level of adopting each lean characteristic and each LSAT component in various hospital departments with the related factors' score of the whole hospital. For instance, the level of adopting lean characteristics stated under LPM, PPI, and CSCI components of the LSAT is compared with hospital A process factors score while the level of adopting those

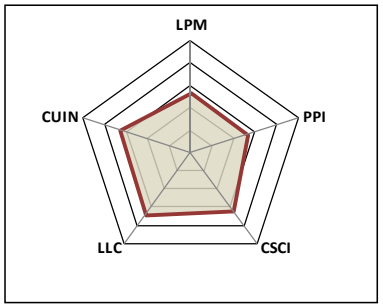
characteristics stated under LLC and CUIN components is compared with hospital A organizational factors score. Based on this comparison, the percentage of those departments with lean characteristics adoption levels less than hospital A related factors score is obtained for each characteristic stated under each LSAT component. Results of this comparison should be used in developing the action items which need to be performed by all departments of hospital A to achieve higher levels of sustainability of lean implementation. However, hospital executives need to determine the cut-off point which identifies these items so that they are challenging though achievable. This cut-off point is determined according to the following:

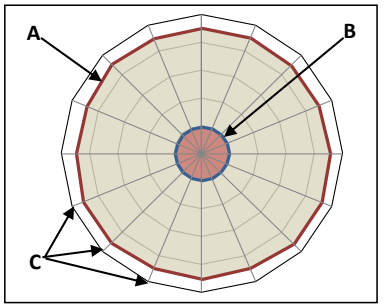
- The targeted factors scores of the hospital, and
- The targeted percentage of hospital departments which must exceed these factors scores.

For illustration, if hospital executives determine that the level of adopting lean characteristics must exceed the obtained factors score in at least 40% of hospital departments, then all characteristics with red, orange, or yellow coded cells must be in the hospital action items. However, the number of these items can be modified by setting higher factors scores targets and/ or decreasing the number of hospital departments with lean characteristics adoption levels that exceed these targets.

In addition, Table 4.5 presents similar percentages obtained for LSAT components to show which area requires more attention in the future developed action plans. It also provides information about the number of hospital departments participating in the assessment process, the leading department(s) for each LSAT component, and factors scores of hospital A.







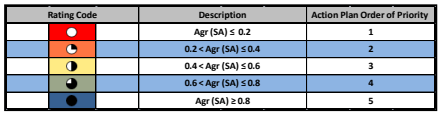
The LSAS	The LSAT radar chart	The LSAT radar chart of individual survey components
LSAS: Lean sustainability assessment space	**LSAT**: Lean sustainability assessment tool	
Definition: a two dimensional space that quantifies the level of implanting lean in surveyed departments/ hospitals.	**Definition**: a chart that shows the level of implementing each component of the developed assessment tool within surveyed departments/ hospitals.	**Definition**: a chart that presents the level of implementing lean characteristics of each LSAT component together with the level of dispersion observed in the reported levels of implementation.
Range: 0 – 1 for both process factors and organizational factors of sustainable lean implementation.	**Range**: 0 – 1 with a 0.2 increment presented in five pentagons.	**Range**: 0 – 1 with a 0.2 increment presented in five circles.
Surveyed departments/ hospitals are placed in one of the four LSAS zones based on the level of implementing these two sets of factors (X,Y).	**LPM**: Lean process maturity (i.e. how close the current setup of hospital processes is to ideal lean processes.)	**A**: level of implementing lean characteristics in surveyed departments/ hospitals.
Making Progress Zone: both factors are considerably enforced (i.e. $X \geq 0.5$ & $Y \geq 0.5$).	**PPI**: Patient/ specimen pathway integration (i.e. assessing the efforts of creating continuous flow of patients / specimens.)	**B**: level of dispersion observed in the reported adoption levels of lean characteristics.
Commencing Zone: organizational factors are more enforced than process factors (i.e. $X < 0.5$ & $Y \geq 0.5$).	**CSCI**: Commitment to safety & continuous improvement (i.e. assessing members' attitudes while developing and updating hospital processes.)	**C:** radar chart data points. They vary based on number of questions of each LSAT component.
Confounding Zone: process factors are more enforced than organizational factors (i.e. $X \geq 0.5$ & $Y < 0.5$).	**LLC**: Lean leadership commitment (i.e. assessing the effectiveness of leadership efforts in reaching hospital-wide lean implementation.)	If the level of dispersion (**B**) of the hospital ≤ 0.2, a single hospital's recommendations report needs to be generated.
Critical Zone: both factors are insignificantly enforced (i.e. $X < 0.5$ & $Y < 0.5$).	**CUIN**: Culture & involvement (i.e. assessing hospital's cultural setup and members' degree of involvement against lean ideal setups.)	If the level of dispersion (**B**) of the hospital ≥ 0.2, multiple departments' recommendations report need to be generated.
	**Recommendations Report:** a report that provides factors' specific recommendations based on current gaps of sustainable lean implementation that have been identified in the generated LSAT radar charts. This report is presented in a table format containing the desired conditions of various lean characteristics included in the LSAT in addition to their current level of implementation coded in colors and icons format. The table, on the left-hand side, shows both color and icon codes and action plan priority orders categorized by various levels of Agreement measures used to construct the related charts.	

Figure 4.28 Charts reading guide

Table 4.5 Executives' summary report

(% Depts. <0.58)	LPM Survey Comp. (% Depts. <0.58)	Question Code	(% Depts. <0.58)	PPI Survey Comp. (% Depts. <0.58)	Question Code	(% Depts. <0.58)	CSCI Survey Comp. (% Depts. <0.58)	Question Code	(% Depts. <0.65)	LLC Survey Comp. (% Depts. <0.65)	Question Code	(% Depts. <0.65)	CUIN Survey Comp. (% Depts. <0.65)	Question Code
31		LPM1	23		PPI1	0		CSCI1	54		LLC1	46		CUIN1
54		LPM2	77		PPI2	69		CSCI2	54		LLC2	46		CUIN2
54		LPM3	8		PPI3	38		CSCI3	46		LLC3	23		CUIN3
54		LPM4	38		PPI4	54		CSCI4	54		LLC4	38		CUIN4
54		LPM5	46		PPI5	54		CSCI5	38		LLC5	38		CUIN5
38		LPM6	31		PPI6	31		CSCI6	15		LLC6	23		CUIN6
54		LPM7	23		PPI7	62		CSCI7	62		LLC7	38		CUIN7
23		LPM8	31		PPI8	23		CSCI8	31		LLC8	62		CUIN8
77		LPM9	62		PPI9	15		CSCI9	69		LLC9	54		CUIN9
69	43	LPM10	31	38	PPI10	31		CSCI10	62		LLC10	31		CUIN10
62		LPM11	31		PPI11	8	29	CSCI11	23	52	LLC11	23		CUIN11
38		LPM12	38		PPI12	8		CSCI12	31		LLC12	31		CUIN12
54		LPM13	62		PPI13	23		CSCI13	69		LLC13	31		CUIN13
62		LPM14	46		PPI14	46		CSCI14	69		LLC14	46		CUIN14
31		LPM15	38		PPI15	31		CSCI15	62		LLC15	23	46	CUIN15
8		LPM16	23		PPI16	38		CSCI16	69		LLC16	46		CUIN16
23		LPM17	0 ≤ % Depts. < 20			8		CSCI17	46		LLC17	31		CUIN17
8		LPM18	20 ≤ % Depts. < 40			8		CSCI18	69		LLC18	23		CUIN18
31		LPM19	40 ≤ % Depts. < 60			15		CSCI19	46		LLC19	38		CUIN19
Number of Participating Depts.		13	60 ≤ % Depts. < 80			31		CSCI20	69		LLC20	31		CUIN20
			% Depts. ≥ 80			15		CSCI21	62		LLC21	46		CUIN21

Survey Components	Leading Department(s)	Factors Scores of Hospital A			
					62 CUIN22
					77 CUIN23
LPM: Lean Process Maturity	A, I	Process Factors Score	0.58		62 CUIN24
PPI: Patient/ Specimen Pathway Integration	D, M				100 CUIN25
CSCI: Commitment to Safety & Continuous Improvement	A, M				92 CUIN26
LLC: Lean Leadership Commitment	F, G, M	Organizational Factors Score	0.65		85 CUIN27
CUIN: Culture & Involvement	G, I				46 CUIN28

It could be argued, however, that the recommendation report should include some information about those lean tools by which surveyed departments/hospitals could achieve the desired conditions of lean characteristics included in the LSAT. This is not done in order enforce the concept early stated by (Dennis, 2002) that transforming to lean is a journey towards perfection, and there is more than one "correct" path to reach the final destination. This final destination is formed through asking an essential question at milestone stations of the journey. This question simply is "what is the need?" Thus, the provided recommendations format help the healthcare organizations answer this basic question in regards to those characteristics which should exist in a sustainable lean implementation setup. Whether or not they fulfill this need using the tools known currently in the lean toolbox is highly dependent on the way they look at these tools. Despite the fact that they prove to be powerful in leading to satisfactory levels of performance, the currently known lean activities and tools should be thought of as the best countermeasures, not solutions, known up to date to handle those performance challenges encountered by business firms in many industries. These activities and tools proved to be powerful when applied to healthcare industry too. However, prior to use any of these tools, healthcare practitioners ought to ensure that a specific selected tool is the best for fulfilling their specific defined needs and apply any modifications that might be desired accordingly.

In order to statistically validate the significance of lean sustainability levels obtained by the developed framework for all departments of hospital A, a set of the nonparametric Friedman tests were conducted on observed factors scores. The results of these tests are summarized in Table 4.6. By alternating the number of blocks between number of factors' scores (2), number of survey components (5), and total number of lean characteristics of all survey components (105),

the p-values of these tests vary for the set of departments that have been analyzed. However, it can be confidently said that the observed variation in these scores is statistically significant at $\alpha=0.05$.

Table 4.6 Friedman test p-values of various framework obtained results

The Null Hypothesis	Number of Treatments	Number of Blocks	DF	P Value
Factors scores of all departments are identical (Blocked by process factors scores and organizational factor scores)	13	2	12	0.044
Factors scores of all departments are identical (Blocked by survey components)	13	5	12	<0.001
Factors scores of all departments are identical (Blocked by individual Lean characteristics under all survey components)	13	105	12	<0.001
Factors scores of different department types (C, A, N) are identical (Blocked by survey components)	3	5	2	0.015
Factors scores of different department types (C, N, A) are identical (Blocked by individual Lean characteristics under all survey components)	3	105	2	<0.001
Factors scores of all departments in the Commencing zone (B, J, L) are identical (Blocked by survey components)	3	5	2	0.022
Factors scores of all departments in the Contentment zone (A, C, D, E, F, G, H, I, M) are identical (Blocked by survey components)	9	5	8	0.022
LPM scores of all departments are identical (Blocked by individual Lean characteristics under LPM survey component)	13	19	12	<0.001
PPI scores of all departments are identical (Blocked by individual Lean characteristics under PPI survey component)	13	16	12	<0.001
CSCI scores of all departments are identical (Blocked by individual Lean characteristics under CSCI survey component)	13	21	12	<0.001
LLC scores of all departments are identical (Blocked by individual Lean characteristics under LLC survey component)	13	21	12	<0.001
CUIN scores of all departments are identical (Blocked by individual Lean characteristics under CUIN survey component)	13	28	12	<0.001

CHAPTER 5 CONCLUSIONS AND FUTURE RESEARCH RECOMMENDATIONS

5.1 Conclusions

Nowadays, healthcare organizations are challenged with improving the level of the offered services while maintaining or even reducing operational related costs. By the beginning of the new millennium, many healthcare institutes started to apply lean practices after witnessing their tremendous impact on the performance of leading firms in the manufacturing sector. However, the rate of applying these practices in healthcare sectors is slower than it should be. In addition, it has been accompanied with enormous obstacles related to proper lean implementation, sustainability of achieved levels of performance, and staff engagement in infinite cycles of continuous improvement towards perfection.

This dissertation proposed a framework to help healthcare organizations quantify their experience with lean. Such quantification is obtained by measuring the agreement level of hospital staff members about the degree of adopting two sets of critical factors of successful lean implementation within their hospital. The proposed framework has been validated by determining the sustainability level of lean implementation within one of U.S. hospitals in State of Florida.

All components of the assessment tool used to obtain the framework quantifying scores have high Cronbach's α values. This indicates their reliability in measuring the underlying constructs of sustainable lean implementation in hospitals. Items included under these

components were developed while considering the complex nature of hospital departments' classification (i.e. clinical services departments, ancillary services departments, and nonclinical services departments).

The analysis conducted throughout the study demonstrated the usefulness of the developed framework in quantifying sustainability of lean implementation on hospital, department types, and individual departments levels. It also showed how to determine the extent of analysis which needs to be performed based on the observed level of dispersion in the received responses. Additionally, it illustrated the importance of the information gathered about hospital's accreditation status and quality improvement efforts in explaining the observed levels of lean characteristics included in the study. Finally, the conducted analysis proved the applicability of the developed framework in assessing the level of adopting characteristics of sustainable lean implementation in hospitals even if lean is not adopted as the management system of the whole hospital.

5.2 Study Limitations and Areas for Future Research

The research data of this dissertation were collected from one hospital only. This has illustrated the benchmarking features of the developed framework in department level. However, illustrating this based on data collected from one hospital, might be viewed as a pilot study analysis, which has been done to assess the reliability of the developed assessment tool and validate the applicability of the developed framework in quantifying the sustainability of lean implementation in healthcare organizations. Thus, future studies should include more than one hospital in order to:

- validate the framework benchmarking capabilities in hospital level,
- investigate the effect of hospital accreditations on the observed sustainability levels of implementing lean within surveyed hospitals,
- investigate the effect of adopting different sets of quality improvement initiatives on the observed sustainability levels of implementing lean within the analyzed hospitals,
- investigate the effect of applying lean for different periods of time on the observed sustainability levels of implementation within surveyed hospitals, and
- investigate the effect of adopting different approaches while transforming to lean on the observed sustainability levels of implementing lean within the analyzed hospitals.

Another limitation observed in this research activity is that all received responses were from the hospital management group. This did not allow for any analysis about the differences which might exist between them and other groups of hospital staff members (i.e. supervisors and frontline staff) in regards to their perception about the level of lean implementation within the investigated hospital. Thus, a future extension to this research activity should include responses from all these groups so that such differences can be explored.

Moreover, some of the items under different components of the developed lean sustainability assessment tool showed low, high, or negative item adjusted total correlations when conducting the omitted item statistics by Minitab. These items were not excluded from the analysis since omitting them from the assessment tool did not show significant change in obtained values of Cronbach's alpha. Thus, conducting a future study with a larger number of responses could justify the exclusion of these items from the developed assessment tool.

Finally, after developing appropriate sets of survey questions, the developed framework has the potential to be used in future studies for assessing six sigma maturity as well as quality management maturity for Malcolm Baldrige National Quality Award criteria.

APPENDIX A STUDY IRB APPROVAL

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Approval of Exempt Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **Haitham A. Bahaitham**

Date: **January 27, 2011**

Dear Researcher:

On 1/27/2011, the IRB approved the following minor modifications to human participant research that is exempt from regulation:

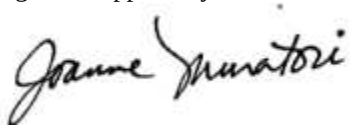
Type of Review:	Exempt Determination
Modification Type:	Study population will be in U.S. and not Saudi Arabia, therefore study title has been changed. In addition, survey instrument will be sent to participants via e-mail in PDF format and returned via e-mail. Revised survey documents uploaded and revised consent document is approved for use.
Project Title:	Lean Sustainability Assessment Model Questionnaire
Investigator:	Haitham A Bahaitham
IRB Number:	SBE-10-07091
Funding Agency:	
Grant Title:	
Research ID:	N/A

This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are made and there are questions about whether these changes affect the exempt status of the human research, please contact the IRB. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Joseph Bielitzki, DVM, UCF IRB Chair, this letter is signed by:

Signature applied by Joanne Muratori on 01/27/2011 11:49:51 AM EST



IRB Coordinator

APPENDIX B STUDY INFORMED CONSENT

EXPLANATION OF RESEARCH

Title of Project: Lean Sustainability Assessment Model Questionnaire

Principal Investigator: Haitham Bahaitham

Faculty Supervisor: Ahmed K Elshennawy

You are being invited to take part in a research study. Whether you take part is up to you.

The purpose of this research is to identify the sustainability level of lean implementation in your hospital. The collected data will be analyzed to enhance the results achieved by implementing such an effective management system within your hospital.

This survey questionnaire is divided into two sections. The first section of the questionnaire covers information about your hospital's quality management system and quality improvement efforts conducted by various hospital departments. The second section of the questionnaire assesses the performance of various hospital departments in regards to lean sustainable implementation based on a set of critical success factors identified from literature.

The first section is about the hospital in general and needs to be filled by a member of the Quality Management or Process Improvement Department while the second section is to be filled by healthcare professionals within each department.

The first section of the designed survey is expected to take 15 minutes to be filled while the second section is expected to take 45 minutes.

You must be 18 years of age or older to take part in this research study.

Study contact for questions about the study or to report a problem: If you have questions, concerns, or complaints, please contact Haitham Bahaitham, Graduate Student, Department of Industrial Engineering and Management Systems, at (407) 272-1155 or by email at haitham@knights.ucf.edu or Dr. Ahmad K Elshennawy, Faculty Supervisor, Department of Industrial Engineering and Management Systems, at (407) 823-5742 or by email at ahmade@mail.ucf.edu.

IRB contact about your rights in the study or to report a complaint: Research at the University of Central Florida involving human participants is carried out under the oversight of the Institutional Review Board (UCF IRB). This research has been reviewed and approved by the IRB. For information about the rights of people who take part in research, please contact: Institutional Review Board, University of Central Florida, Office of Research & Commercialization, 12201 Research Parkway, Suite 501, Orlando, FL 32826-3246 or by telephone at (407) 823-2901.

APPENDIX C SURVEY SECTIONS

C.1 Section One

Dear Member of the Quality Management or Process Improvement Department;

I would like to thank you for the valuable time you are going to spend in responding to this survey which represents the major component of my PhD dissertation. The objective of this study is to identify the sustainability level of lean implementation in your hospital. The collected data will be analyzed to enhance the results achieved by implementing such an effective management system within your hospital.

The success of this study is primarily dependent on your complete honesty while responding to survey questions. Therefore, I would like to assure you that your responses will be treated with strict confidentiality while being combined with other responses for analysis purposes in a way so that no individual respondent will be identified.

This survey questionnaire is divided into two sections. The first section of the questionnaire covers information about your hospital's quality management system and quality improvement efforts conducted by various hospital departments. The second section of the questionnaire assesses the performance of various hospital departments in regard to lean sustainable implementation based on a set of critical success factors identified from literature.

As a member of the Quality Management Department at this hospital, you are invited to complete this questionnaire which represents the first section of the survey. The second section of the survey will be completed by healthcare professionals from various departments of the hospital.

Thank you again for being part of this research effort. Please feel free to email me at haitham@knights.ucf.edu if you have any questions related to the study.

Hospital name: ☐

City: ☐ State: ☐

Hospital opening year: ☐ Bed capacity: ☐

Total number of hospital staff (Both medical and non-medical): ☐

Position of hospital staff filling out this survey: ☐

1. Is this hospital certified against and/or accredited by any of the following? (Select all that apply)

   ☐ ISO9000 Certified since (Year): ☐

   ☐ The Joint Commission (TJC) Certified since (Year): ☐

   ☐ Other (Specify): ☐ Certified since (Year): ☐

   ☐ N/A

2. Has the hospital used any of the following for quality improvement and cost reduction purposes? (Select all that apply)

   ☐ Lean (L) Since (Year): ☐

   ☐ Six Sigma (SS) Since (Year): ☐

   ☐ Lean Six Sigma (LSS) Since (Year): ☐

   ☐ Other (Specify): ☐ Since (Year): ☐

   ☐ None of the above **(Please go to question number 6 of this survey)**

3. Has the hospital adopted this (these) quality improvement initiative(s) in order to meet certification and/or accreditation requirements?

   Lean

   ☐ Yes

   ☐ No

   Six Sigma

   ☐ Yes

   ☐ No

   Lean Six Sigma

   ☐ Yes

   ☐ No

   Other (Specified above)

   ☐ Yes

   ☐ No

4. Has the hospital recognized positive changes in both quality and cost levels of offered services due to implementing these quality improvement initiatives?

Quality Improvements:	Cost Savings:
Lean	Lean
☐ Yes	☐ Yes
☐ No	☐ No
Six Sigma	Six Sigma
☐ Yes	☐ Yes
☐ No	☐ No
Lean Six Sigma	Lean Six Sigma
☐ Yes	☐ Yes
☐ No	☐ No
Other (Specified above)	Other (Specified above)
☐ Yes	☐ Yes
☐ No	☐ No

5. Have these quality improvement initiatives been performed on a hospital level or on a department level? (Select all that apply) (L=Lean, SS=Six Sigma, LSS=Lean Six Sigma, O=Other (Specified above))

☐ Hospital level	○ L	○ SS	○ LSS	○ O

☐ Department level (Select all that apply):

Clinical Services:

☐ Emergency Rooms	○ L	○ SS	○ LSS	○ O
☐ Operating Rooms	○ L	○ SS	○ LSS	○ O
☐ Inpatient Units	○ L	○ SS	○ LSS	○ O
☐ Intensive & Critical Care Units	○ L	○ SS	○ LSS	○ O
☐ Outpatient & Ambulatory Units	○ L	○ SS	○ LSS	○ O
☐ Other (Specify) _____	○ L	○ SS	○ LSS	○ O
☐ Other (Specify) _____	○ L	○ SS	○ LSS	○ O
☐ Other (Specify) _____	○ L	○ SS	○ LSS	○ O

Ancillary Support Services:

☐ Admission & Discharge	○ L	○ SS	○ LSS	○ O
☐ Radiology & Imaging	○ L	○ SS	○ LSS	○ O
☐ Laboratory Services	○ L	○ SS	○ LSS	○ O
☐ Pharmacy & Pharmaceutical Services	○ L	○ SS	○ LSS	○ O
☐ Sterilizing & Reprocessing	○ L	○ SS	○ LSS	○ O
☐ Patient Transportation	○ L	○ SS	○ LSS	○ O
☐ Other (Specify) _____	○ L	○ SS	○ LSS	○ O
☐ Other (Specify) _____	○ L	○ SS	○ LSS	○ O

Nonclinical Support Services:

☐ Purchasing & Supply	○ L	○ SS	○ LSS	○ O
☐ Information System	○ L	○ SS	○ LSS	○ O
☐ Administration	○ L	○ SS	○ LSS	○ O
☐ Accounting	○ L	○ SS	○ LSS	○ O
☐ Maintenance	○ L	○ SS	○ LSS	○ O
☐ Other (Specify) _____	○ L	○ SS	○ LSS	○ O
☐ Other (Specify) _____	○ L	○ SS	○ LSS	○ O

6. Has the hospital implemented lean as the management system of the whole hospital?

☐ Yes, since (Year) ☐

☐ No **(If, No, please go to question 8)**

7. Which of the following approaches was used while transforming to lean organization? (Select all that apply)

☐ Recruiting external consultant to guide the organization through the transformation stage.

☐ Relying on internal expert(s) to guide the organization through the transformation stage.

☐ Exposing internal expert(s) to lean environmental setup at one of the famous adopting lean organizations prior to the leading stage of transformation.

☐ Providing lean basic training to hospital executives, managers, and supervisors before starting the stage of transformation.

☐ Planning and administering lean basic training to all hospital staff members at once.

☐ Planning and administering lean basic training gradually to all hospital staff members.

☐ Starting the transformation throughout the whole organization at once.

☐ Starting the transformation gradually throughout the organization by first selecting a department or a process where results of lean initiatives can be easily and promptly discerned.

☐ Adopting the "No Layoff" policy throughout the stage of transformation to assure job security for all hospital staff members.

☐ Other (Specify): ☐

☐ Other (Specify): ☐

☐ Other (Specify): ☐

(Please stop at this point of the survey. Thank you for your participation. Please click on "Submit by Email" button provided below)

8. Does your hospital consider implementing lean as the management system of the whole hospital?

☐ Yes, starting from (Year) ☐

☐ No

(Thank you for participation. Please click on "Submit by Email" button provided below)

C.2 Section Two

Dear Healthcare professional;

I would like to thank you for the valuable time you are going to spend in responding to this survey which represents the major component of my PhD dissertation. The objective of this study is to identify the sustainability level of lean implementation in your hospital. As the lean management system is basically built on respect for employees and continuous improvement towards perfection, your perception about various daily activities conducted within your department is considered as a significant measure for the success that has been made so far in your lean implementation within your healthcare organization. The collected data will be analyzed to enhance the results achieved by implementing such an effective management system within your department as well as other departments in your healthcare organization.

The success of this study is dependent on your complete honesty while responding to survey questions. Therefore, I would like to assure you that your responses will be treated with strict confidentiality while being combined with other responses for analysis purposes in a way that no individual respondent will be identified.

This survey questionnaire assesses the performance of your department in regard to your lean sustainable implementation based on a set of critical success factors identified from the literature. These factors have been grouped under five major components comprising the survey. These components are:

1 Lean process maturity: this component describes the ideal setup of various processes within your department based on defined characteristics of ideal lean processes.

2 Patient/ specimen pathway integration: this component illustrates the ideal way of connecting various lean processes and the way of handling resource requests and demand fluctuation within your department and the whole hospital to create a continuous flow for patients/ specimens.

3. Commitment to safety & continuous improvement: this component describes individual, departmental, and organizational ideal safety and continuous improvement attitudes while developing and updating the lean processes within the whole hospital.
4. Lean leadership commitment: this component demonstrates the ideal leadership characteristics that must exist in order to have an effective hospital-wide implementation of lean.
5. Culture & involvement: this component presents the ideal cultural setup of a lean hospital as well as the level of involvement expected from various members of its organizational structure.

Prior to presenting these components, the survey begins with a question for assessing your level of awareness about various lean activities and tools. Thank you again for being part of this research effort. Please feel free to email me at haitham@knights.ucf.edu if you have any questions related to the study.

Hospital name: ☐

Position of hospital staff filling out this survey: ☐

Department of hospital staff filling out his survey: ☐

Which of the following lean activities/ tools are you familiar with? (Select all that apply)

- ☐ Types of process waste: motion, waiting, inventory, transportation, errors and defects, overproduction, overprocessing, and knowledge disconnection
- ☐ Waste elimination: identifying & eliminating non-value adding activities
- ☐ Process stabilization
- ☐ Total productive maintenance (TPM)
- ☐ Cellular layout workplace
- ☐ Pull
- ☐ Kanban
- ☐ Self inspection: quality at source
- ☐ Process capability and variation reduction
- ☐ Batch size reduction
- ☐ Gemba walk: walking around processes to identify areas for improvement
- ☐ Control department concept
- ☐ Work standardization
- ☐ Andon system: stopping the process when error/ defect observed
- ☐ All of the above
- ☐ None of the above
- ☐ Other (Specify) ☐

- ☐ Jidoka: developing defect-free processes by doing things right the first time
- ☐ Continuous improvement (Kaizen events)
- ☐ Just-in-time (JIT)
- ☐ Continuous flow
- ☐ Error proofing (Poka-yoke)
- ☐ Heijunka: workload leveling to smooth out demand fluctuation
- ☐ Point of use storage (POUS)
- ☐ Quick changeover/ Quick setup
- ☐ 5 whys: root cause analysis
- ☐ 5S: sort, set in order, shine, standardize, & sustain
- ☐ A3 thinking
- ☐ Hoshin planning
- ☐ Visual & workplace organization
- ☐ Value stream mapping (VSM)
- ☐ Layout optimization: steps & transportation reduction
- ☐ All of the above
- ☐ None of the above
- ☐ Other (Specify) ☐

Based on your experience with daily activities conducted in your department, please rate each of the following statements using the provided drop-down five-level Likert scale.

Lean Process Maturity

1. Each Process within my department has a designated name.

2. Each process within my department has a process owner in-charge of conducting process training and assuring conformance to process performance standards.

3. All processes within my department have clearly defined start and end points.

4. All processes within my department have clearly defined outcomes to be achieved smoothly.

5. All processes within my department have clearly defined steps required to achieve desired outcomes.

6. All processes within my department have a clearly defined sequence of steps which must be followed to achieve desired outcomes.

7. All processes within my department have clearly defined durations for conducting process steps.

8. The competency level of my department members is high enough to assure achieving process defined outcomes.

9. Processes within my department are NOT frequently interrupted due to unavailability of designated staff member(s).

10. Processes within my department are NOT frequently interrupted due to unplanned equipment maintenance.

11. Processes within my department are NOT frequently interrupted due to unavailability of essential related supplies.

12. Processes within my department are NOT delayed due to unavailability of clear instructions about the way to perform process related task(s).

13. Processes within my department are NOT delayed due to a disorganized workplace.

14. Standards of performing processes within my department are available in a simple clear format (i.e., drawing or picture) that visually illustrates desired process performance conditions.

15. The know-how and experience of hospital staff in regard to how to perform process steps is captured within process standards.

16. Staff trainings are designed and updated based on the standards developed in the hospital/ department.

17. Change of process standards is triggered by newly defined forms of waste (i.e. non-value adding activities).

18. Change of process standards is done by following a scientific-based improvement methodology (e.g., PDCA: Plan-Do-Check-Act).

19. Change of process standards targets increasing staff utilization prior to increasing equipment utilization.

Patient/ Specimen Pathway Integration

1. Hospital resources (staff, supplies, data, and equipment) are pulled (brought) to patient's point of care as needed by delivered value.

2. The workload of my department is frequently leveled to smooth out drastic demand fluctuation in offered services.

3. My department members are continuously developing multitasking skills to respond to fluctuation in department workload (i.e., improving manpower utilization).

4. All processes of my department form a pathway sequenced according to a convenient patient/ specimen flow within the department.

5. All consecutive processes within my department patient/ specimen pathway(s) are directly connected.

6. All consecutive processes within my department patient/ specimen pathway(s) are linked based on supplier-customer relationship (i.e., downstream processes are customers of upstream ones while upstream processes are suppliers of downstream ones).

7. All processes within my department patient/ specimen pathway(s) are directly connected to their internal and external suppliers.

8. All processes within my department patient/ specimen pathway(s) have a clear signaling mechanism with their suppliers to send requests and receive responses about resources required for delivering patient defined values.

9. All consecutive processes in my department pathway(s) are synchronized to eliminate delays in tasks performed on patients/ specimens.

10. Each patient/specimen pathway in my department has a designated owner in-charge of assessing related tasks to assure conformance to pathway performance standards.

11. Patient/specimen pathway(s) within my department have a clearly defined start and end point at which they interface with other patient/ specimen pathways in the hospital.

12. Patient/specimen pathway(s) **within my department** are frequently standardized (i.e., modified) to eliminate newly defined forms of waste (i.e., non-value adding activities).

13. Consecutive patient/ specimen pathways within the hospital are synchronized to eliminate delays in tasks performed on patients/ specimens.

14. Consecutive patient/ specimen pathways **within the hospital** are frequently standardized (i.e., modified) to eliminate newly defined forms of waste (i.e., non-value adding activities).

15. Various department patient/specimen pathways are integrated to form main pathways of the whole hospital.

16. Main hospital pathways are formed based on various patient defined values (i.e. patient condition and type of needed services).

Commitment to Safety and Continuous Improvement

1. Hospital executives support conducting continuous improvement initiatives throughout the whole hospital.

2. **Our hospital executive(s)** have a daily walk-through patient/ specimen pathway(s) **within the whole hospital** to identify new areas for improvement.

3. **My department manager(s)** have a daily walk-through patient/ specimen pathway(s) **within our department** to identify new areas for improvement.

4. **My department members** share the knowledge about **department** overall performance through using a simple comprehensive information display system.

5. **Our hospital staff members** share the knowledge about the overall performance of the **hospital** through using a simple comprehensive information display system.

6. The outcome of each process in my department is inspected prior to proceeding to the next process.

7. All consecutive processes within my department have a feedback mechanism to contain errors/ defects prior to having them spread into other hospital departments.

8. All my department members have the right to stop any process within the whole hospital and interrupt patient/ specimen pathway(s) upon observing the occurrence of an error or defect related to **process desired outcomes**.

9. All my department members have the right to stop any process within the whole hospital and interrupt patient/ specimen pathway(s) upon observing the occurrence of an error or defect related to **patient safety**.

10. All errors detected in the hospital are attended by multidisciplinary teams, made of all stakeholders in relation with affected process(es), in order to be traced to their ultimate root cause(s).

11. All safety incidents detected in the hospital are attended by multidisciplinary teams, made of all stakeholders in relation with incidents' causing process(es), in order to be traced to their ultimate root cause(s).

12. My department members have an adequate knowledge about their line of support (i.e., supervisors and/or managers) whom they should contact when their process(es) get out of control.

13. My department members have a clear signaling mechanism that directly conveys their support requests to their line of support.

14. Our hospital has a standard procedure for handling support-related requests (i.e., response time, team members who should attend within each hospital zone, and any other alternative plans if needed) for each process within the entire hospital.

15. All continuous improvement efforts of my department members are conducted by following a scientific method (e.g., PDCA: Plan-Do-Check-Act).

16. My department members are trained on the continuous improvement method adopted by the hospital.

17. All continuous improvement efforts of my department members are made to advance one or more of the hospital's strategic objectives.

18. All continuous improvement efforts of my department members are conducted with clearly expected outcomes.

19. All continuous improvement efforts of my department members are conducted under the guidance of a teacher (i.e., a process owner).

20. Continuous improvement ideas flow from the department staff towards hospital management through an established suggestion program.

21. Results of continuous improvement efforts conducted at the department level are reported to hospital management on a regular basis.

Lean Leadership Commitment

1. Hospital executives share with all department members a clear vision about the meaning of process perfection.

2. Hospital executives share with all department members a clear vision about what constitutes patient needs.

3. Hospital strategic objectives are developed based on patient defined needs (i.e., values).

4. Hospital strategic objectives are patient-centered with clear goals related to:

- advancing the productivity level of hospital processes
- advancing the quality level of hospital processes
- reducing the cost of hospital processes
- reducing both lead and processing time of hospital processes
- advancing the safety level of hospital processes
- improving the environmental setup of hospital processes
- improving the morale level of hospital staff, patients, and suppliers

5. Hospital executives have established measures to reflect the performance of the entire hospital towards achieving hospital strategic objectives.

6. Our department manager has established measures to reflect the performance of our department towards achieving hospital strategic objectives.

7. Advancement towards fulfilling hospital strategic objectives is measured on a daily basis.

8. Hospital strategic objectives are known by all members of my department.

9. My department members perceive hospital strategic goals as challenging though achievable.

10. On a departmental level, hospital strategic objectives are transformed into actionable plans.

11. My department members perceive our departmental goals and objectives as challenging though achievable.

12. On an individual staff level, hospital strategic objectives are transformed into specific responsibilities and performance targets.

13. My department is accountable for coordinating the effort of different departments involved in achieving cross-functional goals which fall under its specific plan for achieving the hospital's strategic objectives.

14. Other hospital departments consider supporting my department in achieving its cross- functional goals when developing the plan of their own departments.

15. On the hospital executive level, all department plans are incorporated into one master plan to assure their alignment towards achieving defined strategic objectives.

Culture & Involvement

1. My department members understand lean as a business philosophy which creates value through creating trust and fulfillment.

2. My department members understand that lean is more than waste elimination and cost reduction.

3. Continuous improvement initiatives are viewed by my department members as efforts conducted to attack problems and processes not people.

4. Process continuous improvement is viewed by my department members as a way of work and not just a quality initiative.

5. My department members have a common perception that process redesign should be based on patient defined needs.

6. All my department members are capable of identifying patient needs and countermeasures or solutions required to fulfill those needs.

7. All my department members are capable of identifying different types of waste which constitute non-value adding activities within their processes.

8. Capabilities of my department members are progressively improved through attending structured training about various lean activities and tools.

9. Capabilities of my department members are progressively improved through continuous participation in process improvement projects.

10. Lean leaders are continuously developed from hospital staff members through simultaneous doing and learning infinite cycles.

11. My department members are encouraged to develop and improve standards related to their processes.

12. My department members are encouraged to utilize their creativity to gradually improve their processes prior to jumping to capital investment solutions.

13. My department members are accountable for conducting continuous improvement initiatives to solve specific problems related to their processes.

14. Hospital supervisors, managers, and executives are involved in process improvement activities through providing necessary support to my department members.

15. All problem solving and continuous improvement activities are conducted by multidisciplinary teams made of all stakeholders affected by developed solutions and/ or redesigned process(es).

16. All problem solving and continuous improvement teams are formed from frontline hospital staff members (i.e., nurses, technicians, and allied health personnel) with the support of supervisors and managers from all levels of the hospital.

17. All problem solving and continuous improvement teams have at least one member of the hospital executive team as a champion.

18. A group of my department members meets regularly to identify areas for improvement within our department.

19. A group of hospital staff members from different hospital departments meets regularly to identify new areas for improvement on the hospital level.

20. There is at least one of my department members representing our department in hospital meetings for identifying various areas for improvement.

21. The hospital has a suggestion program through which my department members can deliver their ideas for improvement to hospital management.

22. The hospital suggestion program has a mechanism for **prioritizing** implementation of staff suggestions based on their relevance to hospital strategic objectives.

23. The hospital suggestion program has a mechanism for **expediting** implementation of staff suggestions, even if they are sub-optimal, based on their relevance to hospital strategic objectives.

24. Our hospital has a clear performance-based reward and recognition program to value staff participation in process continuous improvement.

25. My department members are rewarded based on the number of continuous improvement suggestions they submit annually.

26. My department members are rewarded based on the number of continuous improvement events they attend annually.

27. Hospital staff members, released due to improving manpower utilization within a process, are redeployed to other value adding processes in the hospital.

28. Our hospital has training and career advancement policies which are based on equal skill development opportunities for all hospital staff members.

(Thanks for your participation. Please click on "Submit by Email" button provided below)

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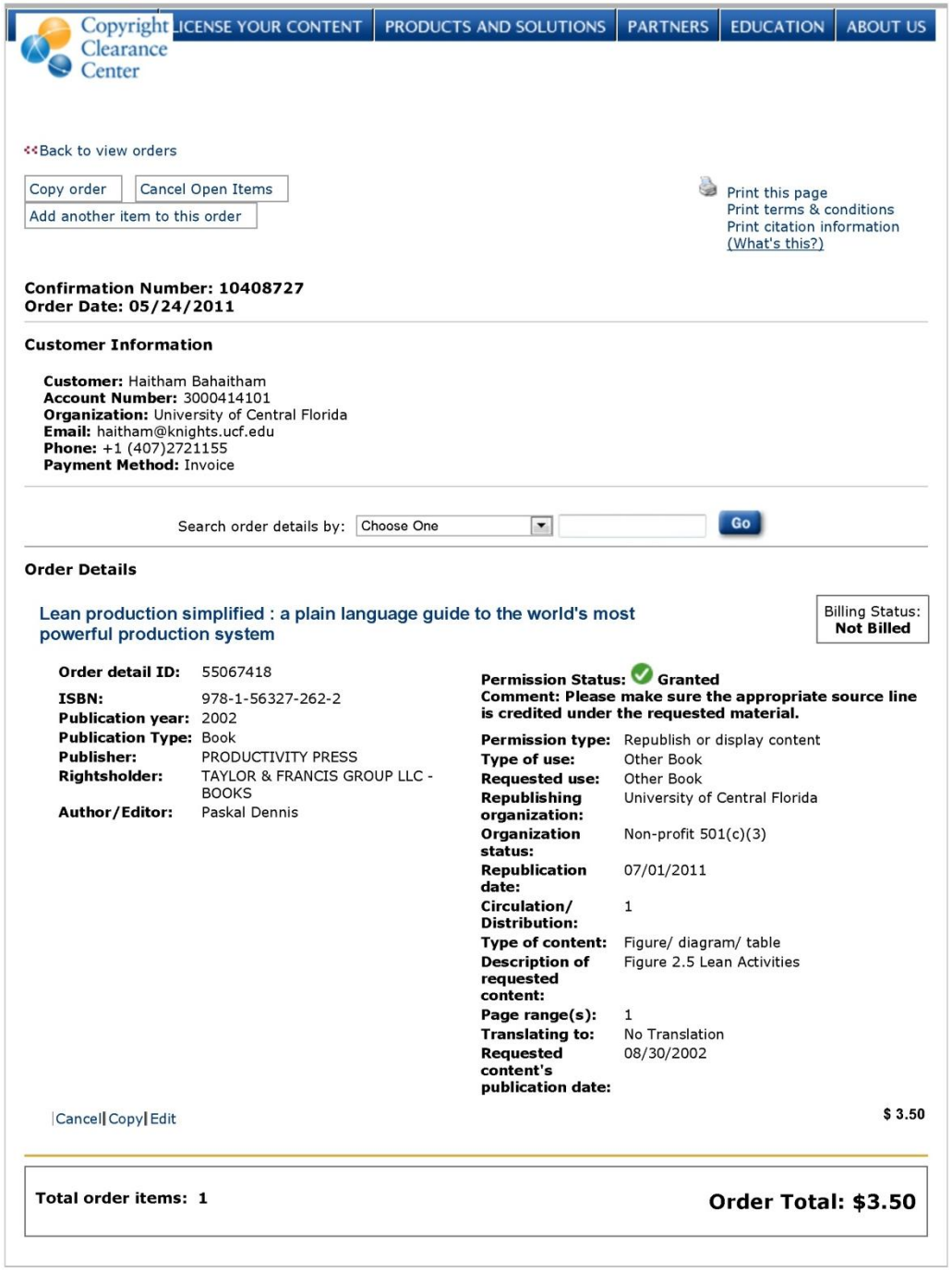
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