LEAN SIX SIGMA PROJECT MANAGEMENT

An application in the Mission Critical Facilities Industry

By

Zagoras E. Nikitas

A THESIS REPORT

Presented to the Project Management Program in the

School of Management of

City University of Seattle

In Partial Fulfillment of the Requirements

For the Degree of

MASTER OF SCIENCE in PROJECT MANAGEMENT

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This Master Thesis was elaborated in the frame of the collaboration of the City University of Seattle and the Graduate Technological Education Institute (T.E.I.) of Piraeus to fully implement at TEI of Piraeus Campus the CU's MS in Project Management Program approved by the Hellenic Ministry of National Education and Religion Affairs as by decision E5/58291 published in the Hellenic Government Gazette (FEK) B/924/5- July-2005.

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Dedicated to my father, Eleftherios N. Zagoras who passed away in 2007 at, age 68.

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I would like to acknowledge my advisor Dr. Besseris for his support and priceless guidance. Furthermore the employees of PULSAR S.A. for giving me the opportunity to capture real evidence, facts and data that helped me complete my research.

Finally, the most important acknowledgement goes to my classmates for sharing with me their valuable experiences and perspectives for the past to years.

BIOGRAPHY

Nikitas E. Zagoras was born on December 3rd, 1981 (Roman calendar) in Athens, Greece. After graduating with his high school diploma in 1999 from 2nd High School of Alimos, he attended the T.E.I. of Piraeus, Attica (School for Technological Applications) for his undergraduate degree. In parallel to his studies, for his degree, he worked as a part-time assistant project manager for a domestic constructions company. He graduated with his Bachelors in Electrical Engineering in 2007 while he was fulfilling his military obligations.

Nikitas continued his professional career in industrial construction and specialized in MCF (Mission Critical Facilities). In October 2008, he joined the rank of graduate students at City University of Seattle, T.E.I. of Piraeus campus, for his Masters of Science in Project Management. His research focused on Lean Six Sigma applied in MCF construction management. He was advised by Dr. George Besseris.

Abstract

This research aims to discover if Lean Six Sigma can add value on an organization that specializes in Mission Critical Facility construction projects. The type of facility that will concern us the most is the Data Center. The company we will study is called PULSAR SA. This name is fictional because the original company wished to keep its anonymity. After carefully reviewing the data we have gathered we selectively chose three Lean Six Sigma tools for this case. This selection is objective and varies according to the type of the organization and the nature of the issues to be resolved.

Key words: *Data Center, Construction, Project Management, Project Quality Management, Lean, Six Sigma, Mission Critical Facilities, FMEA, Cause & Effect Matrix, Pareto Chart.*

Table of Contents

List of Figures & Tables

1. INTRODUCTION

There is a tendency in processes to move towards states that are more chaotic, but only if they are left unmanaged (like entropy in physics). In our case waste is a natural phenomenon, which every project has to encounter, it is also a result of poor management. In order to minimize the waste specific measures have to be implemented. We will refer to these measures in more detail in the following chapters.

Firstly, we have to refer to the knowledge area that all these are incorporated. According to Project Management Institute one of the nine knowledge areas is Project Quality Management (PQM). “Project Quality Management includes the processes and activities of the performing organization that determine quality policies, objectives, and responsibilities so that the project will satisfy the needs for which it was undertaken. It implements the quality management system through policy and procedures with continuous process improvement activities conducted throughout, as appropriate.” (PMI, 2008)

Project Quality Management in simple words is a combination of Quality Management (QM) and Project Management (PM). PQM is fully aligned with the theories expounded by quality gurus (W.E. Deming, J.M. Juran and P.B. Crosby) as well as other non-proprietary approaches (TQM, Six Sigma, Lean etc.). Six Sigma focuses into fixing problems in processes while Lean Management concentrates on the interconnections between the processes. The most important role in our case will be given to the Lean Six Sigma approach. Lean Six Sigma (LSS) is a methodology that puts both Six Sigma and Lean Management into the challenge.

The case we will refer to is about a company that is involved in the construction industry. This company is called PULSAR S.A. and specializes in constructing Mission Critical Facilities (MCF) and especially Data Centers (DC).

There are various issues; that have appeared throughout PULSAR's lifetime, concerning construction Project Management. These all will be addressed into the problem statement section. We will attempt to address every issue additionally we will be confront; analyze and provide effective solutions. Our attention will be concentrated at minimizing the waste that appears in the form of errors, slow processes, poor risk assessment, lack on information, rework and schedule slippage (Muir, 2006).

In conclusion, the importance of our research study is of great significance to PULSAR, because it will help in improving the processes, in saving resources and most importantly in raising customer satisfaction levels exponentially. It is obvious that this study is clearly related to various modules from this MSc Project Management program such as:

- PM 511 - Project Quality Management
- PM 512 - The Customer in the Project Process
- PM 514 - Project Management - Program Integration

2. PROBLEM STATEMENT

PULSAR is a company that designs, constructs, operates and evolves Neutral World-Class Data Centers (DC) and data rooms in Greece and other European countries. PULSAR also offers services based on world class standards. Efforts have been made to constantly improve the total customer value through excellent customer services, strategic partnerships and associated products. An attempt to embed Quality Management tools, throughout the organization, is underway. While this attempt progresses the company has traced wastes (non-value adding activities).

Muda (無駄) "is a traditional Japanese term for an activity that is wasteful and doesn't add value or is unproductive" (Sanseidō Co., 2006). It is also "a key concept in the Toyota Production System (TPS) and is one of the three types of waste; Muda, Mura and Muri" (Womack, Jones, & Roos, 1990). Pulsar has decided to focus in waste reduction as it is an effective way to increase profitability.

Wastes have been divided in two major categories:

- Time. Reducing the time it takes to finish an activity from start to finish is one of the most effective ways to eliminate waste and lower costs (transportation, motion, wait, over-processing).
- Resources. To minimize cost, a company must produce with accuracy what the customer needs (inventory, defect).

3. REVIEW OF LITERATURE

Our research led us through various paths. In order to make this review as smooth and readable as possible the contents of this chapter begin with general information that will finally lead us, while escalating, to the particular information that we really seek. We will begin with Quality Project Management, as it is one of knowledge areas according to PMBoK, in order to address issues that are relevant with quality into the Project Management field (PMI, 2008).

We will continue with Lean Manufacturing which is the inspiration for Lean Construction. Both approaches have the intention to minimize wastes in every process and deal with potential bottlenecks (Theory Of Constraints). Lean Manufacturing was and is a very successful management model, for more fifty years, in the Toyota Production System (TPS) and Toyota Development System (TDS). The difficulty as well as the challenge is the transition from the manufacturing into the project environment. Our next stop is Six Sigma which has met, analogically to Lean, a tremendous success the past few years. The goal of Six Sigma is to reduce variances and produce products and services of high quality. Finally we refer to the Lean Six Sigma approach which is a method that combines the advantages of Lean as well as those of Six Sigma, the result is an output of high quality with the minimum resources. Both approaches have a solid, common ground and this is customer satisfaction, in simple words customer will receive exactly what he needed and paid for.

3.1 Project Quality Management

More than twenty years ago, a revolution in quality management has begun. The first attempts focused on product quality, leadership quality and project management quality.

Nowadays, with the threat of a recession, management recognizes the need for quality improvement. Today's crisis has some common elements with the recession of 1979 to 1982; when Ford, General Motors, and Chrysler faced serious problems. From 1989 to 1994, high-tech engineering companies didn't pay much attention in product development in correlation between PM, TQM and engineering. This was a management deficiency that was discovered after 1994.

Customers in the project process have a critical role nowadays more than ever. They are the project stakeholders who literally "pull the strings" and demand:

- Higher performance
- Faster product development
- Higher technology
- Precision in project specifications
- Efficiency into process
- Lower contractor profit margins
- Fewer wastes

In a few words, the customer aims for the top and is willing to push everybody to the limit so as to satisfy his expectations. Every project is developed in the rapidly changing global market environment. Two are the critical factors that can, and will, affect quality contrasted with market expectations. These are:

● Salability: "The balance between quality and cost."

● Produceability: "The ability to produce the product with available technology and workers, and at an acceptable cost."

(Kerzner, 2009)

3.2 Lean Manufacturing

Taichi Ohno is considered by many the father of the Toyota Production System (TPS), as well as the father of Lean manufacturing philosophy. Ohno after thirty years of valuable experience in the manufacturing industry, from process designing to deploying new techniques, he reached to what most consider the essence of Lean.

Ohno states at one of his books "The primary objective of the Toyota production system was to produce many models in small quantities" (Ohno, 1988). The TPS focuses mainly in the production efficiency which is increased by the waste elimination. Womack, Jones and Roos (Womack, Jones, & Roos, The machine that changed the world: The story of lean production (1st ed.), 1991) have defined eight types of waste, one more than Ohno, called Muda in Japanese (無駄). They are:

1. Defects in products.
2. Overproduction.
3. Inventory waiting to be processed.
4. Unneeded processing.
5. Unnecessary movement of people.
6. Unnecessary transport of goods.
7. People waiting for input to work on.
8. Design of goods and services that do not satisfy customer needs. (Leach, 2005)

Others have identified and added a ninth waste, which is Haste (Robertson, 2007).

The approach of Lean Production Management suggests managing the flow, from processes to process steps, in order to reduce all of the types of waste. Cusumano and Kentaro (Cusumano & Kentaro, 1998) are attempting to move Lean ideas to certain elements of multiple project systems in their book "Thinking Beyond Lean". They put attention on spreading the concepts of Lean beyond the microcosm of a single project but into an holistic approach of portfolio management. The final goal will be an organization that thinks and acts "leaner"; that means that everyone will have the responsibility to eliminate wastes around them, which sabotage the daily work flow and eventually the total performance. The Theory Of Constraints (TOC) is a common practice to find the weak points that need extra attention. Against the common belief that this approach could lead us to separate paths, we discover that the goal is common and only with a systemic approach Lean will provide us the best possible results (Leach, 2005).

3.3 Lean Construction

Lean Construction is an approach originally started by Koskela L. (1992); others followed and contributed in making this approach more complete, like Ballard G. and Howell G. (1994). This approach aims to manage and improve construction management processes by minimizing the cost thus maximizing the value while considering every customer need (Howell & Koskela, 2002).

It started as an overall attempt to import the Lean Manufacturing techniques into project management and more specifically into construction project management. The name "Lean Construction" was used by the International Group for Lean Construction (IGCL) in its first meeting in 1993. (Townend & Gleeson, 2007)

Lean Project Delivery System consists of four interconnected phases:

1. Project definition
2. Lean design
3. Lean supply
4. Lean assembly

According to LPDS a lean assembly begins with the arrival of materials and ends with the project handover. Lean assembly is a predominant factor, because is strongly connected with the human and technical structure of this phase. Because LCM is an approach that is evolving day by day, its implementation techniques follow a more experimental approach; practices are designed and tested daily, through trial and error until they can be successfully adopted at companies (Ballard G. , 2000). On the contrast lean production techniques are all interconnected through a common basis (Feld, 2001) (Liker & Meier, 2006).

3.3.1 Flow Variability

In lean manufacturing, at production level, the impact of flow variability is a serious issue; in Japanese called Heijunka (平準化). Special production leveling controls are set in order to respond to the fluctuating demand levels. The fluctuation is controlled by the optimization of the sequence of products with minimum batch sizes. Keeping batches smaller, helps in creating a more agile model, this way fluctuation can be managed by adjusting with precision the production volume and simultaneously allocating the necessary resources.

Some techniques that are associated with production leveling are:

- Product sequence scheduling
- Flexible standard operations
- Multifunctional layout design
- Total preventive maintenance (Ballard G. , 2000).

Flow variability has a major impact in lean construction projects because the “late finish” of one task can affect the total time needed to complete the project. A new technique has been created for this purpose; the Last Planner is a technique that supports the project plan virtualization in a timely manner (Ballard G. , 2000).

Last planners are called the people accountable for the administration of individual tasks at the operational level. The Last Planner process starts after the Reverse Phase Schedule (RPS) is completed. The RPS is a detailed work plan specifying the project task sequences (Howell & Ballard, 2003).

Having the RPS as a guide, with just a preview of the project schedule we can identify the activities that will be completed shortly as well as the ones that have already been completed. Every planner is responsible to prepare, every week, a work plan in order to control the workflow and the workload. In the unfortunate case that a task is not completed on time, a planner must rapidly search for the root cause of the variance and develop a counteraction. This way future recurrence of this problem will be handled more effectively.

3.3.2 Process Variability

Autonomation, in Japanese called Jikoda (自働化), "is the notion that immediate action should be taken to prevent defects at the source so that they do not flow through the process" (Salem, Solomon, Genaidy, & Minkarah, 2006). In manufacturing the inspection routine provides the employees the autonomy to check their machinery therefore they are able to identify any defective products. Consequently the production will stop and the procedure of identifying the root cause begins. "Fail-safe" or "Mistake-proof", in Japanese known as Poka-yoke (ポカヨケ), is the set of devices that are used in manufacturing, to automatically prevent defects from going to the next process (Shingo, 1985).

Usually it is very difficult to trace defects during the project execution phase. If the defects are discovered at the controlling or the operations phase it too late and the creation of waste is inevitable. So Lean Construction concentrates mostly on preventing defects. Failsafe tactics can be implemented on site to ensure acceptable quality on all tasks, giving a more proactive attitude to the project management (Tommelein & Milberg, 2003).

3.3.3 Transparency

A fundamental rule of lean manufacturing is that any resource that does not contribute in improving the overall performance is regarded as waste and should be eliminated.
The 5S (Five S) is a Lean tool that helps in creating a self-running, self-regulating organization. They 5S are:

- Sort (Seiri, せいり), Organizing your work environment (from hardware tools to paperwork)
- Straighten (Seition, せいとん), Creating a daily ease of use around you
- Standardize (Seiso, せいそ), Maintaining everything clean and functional
- Shine (Seiketsu, せいけつ), Developing practices to sustain the above 3S
- Sustain (Shisuke, しつけ), Inspiring everybody to use the above 4S

  (Gitlow, 2009)

Lockheed Martin and other organizations have added one more S (5S+1). The additional S is for Safety and represents the removal of hazards and other on-site dangers (Michael, 2003). In construction, the Five S supports an ergonomic job site, where materials flow efficiently and all the tasks involved are completed smoothly (Santos, 1999).

3.3.4 Continuous Improvement

Continuous improvement, in Toyota Production System known as Kaizen, is not a specific technique rather than a mentality. The true value of continuous improvement is in cultivating an atmosphere of continuous learning, an environment that not only accepts changes but actually embraces them (Liker, 2004).

The essence of kaizen lies in all techniques that able to drive continuous improvement using problem solving, creative thinking and high adaptability levels. Employees are encouraged to actively participate in process improvement. Project teams meet periodically in order to recommend new tactics for daily issues that affect their workplace efficiency.
The most common issues are quality, maintenance, cost reduction and safety. Teams contribute to potential solutions with their valuable experiences. The most crucial factor is learning, everybody must adopt an “unlearn outdated techniques - learn updated techniques” state of mind. Targets are set in cooperation with all the personnel, they give their input on their daily progress, this is accomplished with informal meetings that intent to develop and improve process (Abdelhamid & Mastroianni, 2003). At the end of every month the new targets are communicated throughout the organization (Schwaber, 2002).

Everything is examined in detail; then an attempt is made to elevate new ideas and suggestions in order to identify alternative ways of doing the work. The PDCA loop is used to develop this study.

Figure 1

A Plan – Do – Check – Act illustration.

The current version of ISO 9001 defines PDCA as follows:

- Plan is the phase were the establishment of objectives and processes that are necessary to deliver result in accordance with customer requirements and the organization policies, takes place.
- Do is the phase were the planning implementation takes place.
- Check comes next and involves the monitoring and measuring of processes and products against policies, objectives and requirement. The results are then reported.
- Act is the final step and requires actions that aim to improve the process (Gupta, 2006).

3.4 Six Sigma (6σ)

Six Sigma (6σ) is often described as a highly sophisticated statistical method used by engineers in order to reduce defects and variance in products and processes. Measures and statistics are key elements of Six Sigma improvement; but there is more than that. A different definition of Six Sigma is that its goal is the perfection pursuit in meeting customer requirements. This is correct too; the truth is that the term “Six Sigma” itself cites to a statistical method which targets performance of operating with only 3.4 defects out of a million products. Six Sigma is a uniquely customer driven method which supports a disciplined use of facts and data with statistical analysis, assiduous attention in managing, continuous improvement, and reinvention of processes.

It is a goal that very few companies or organizations can claim to have achieved. A definition developed, by Pande, Neuman and Cavanagh, that captures the extent and plasticity of Six Sigma as a way to boost performance is provided below. Six Sigma is a “comprehensive and flexible system for achieving, sustaining and maximizing business success” (Pande, Neuman, & Cavanagh, 2000).

After we have successfully implemented Six Sigma the benefits are many, vary and comprise:

- Cost reduction
- Productivity advancement
- Market share expansion
- Customer satisfaction
- Cycle time reduction
- Major defect reduction
- Culture change
- New product or service development (Pande, Neuman, & Cavanagh, 2000).

This story goes back to the 1990s, when Six Sigma was introduced to the broad audience by Motorola. Recent stories of Six Sigma success; from General Electric, Sony, AlliedSignal, to Motorola, have drawn attention of investors and propagated the popularity of this business strategy. The Six Sigma practitioners are sometimes called “black belts” “top guns” “change agents” or “trailblazers” this depends on the company that deploys this strategy. These professionals are trained in the Six Sigma philosophies and techniques. A Six Sigma initiative in a company is targeted in changing the organizations culture through breakthroughs, improvements and by focusing on an out of the-box thinking. This will contribute in achieving aggressive and stretched goals (Kerzner, 2009).

A powerful mindset in Six Sigma is DMAIC, which is a model that helps in solving a problem. It prevents us from wasting hours in arguing about how to solve the problem and allows the project team to focus on the problem resolution itself (Goldsby & Martichenko, 2005).

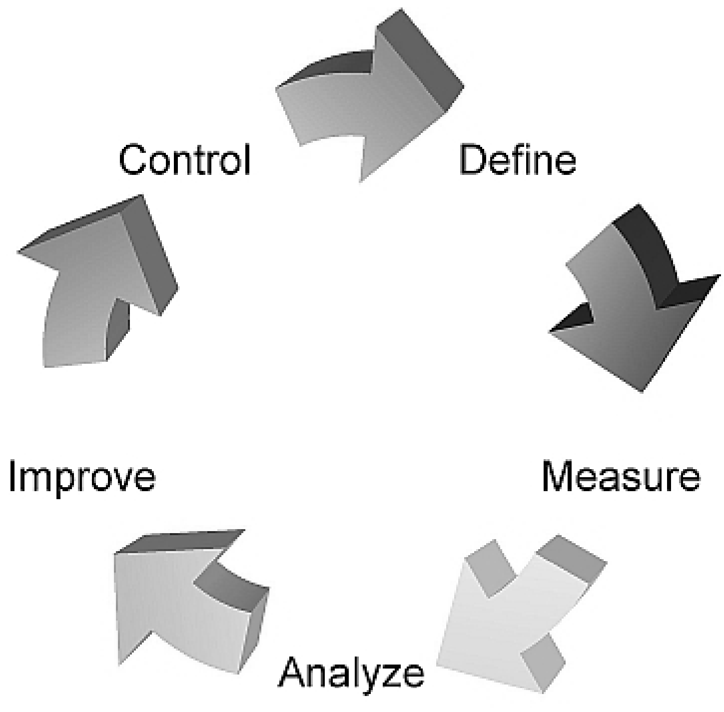

Figure 2

A Define – Measure – Analyze – Improve - Control illustration.

3.5 Lean Six Sigma project management

Six Sigma and Lean in the past was viewed as distinct and dissimilar improvement methods, that was until the late 1990s. Nowadays, many organizations have begun to integrate Six Sigma, Lean, Project Management and business process. All these are strategically aligned with the organizations vision and mission.

The fusion of the four bodies of knowledge (BoKs) as shown in *Figure 4* has been accomplished using several viable models. Nowadays consultants and professionals in the field tend to integrate methods. Usually after they reach a certain level of expertise in both areas they combine their knowledge to achieve the level of improvement they desire. This is a common tactic on an academic level as well as throughout the organization (Mader, 2008).

The utilization and concentration of Six Sigma is to fix processes. On the other hand Lean ponders on the interconnections between the processes. Reducing the defects is the target of Six Sigma. The root causes of the defects are examined thoroughly and efforts are made to eliminate those causes. Lean emphasizes into defects but from another point of view, it considers defects as the cause of tardiness. To sum up both philosophies aim to improve the product's or service's overall quality but at the same time they concentrate in delivering right and fast (Muir, 2006)

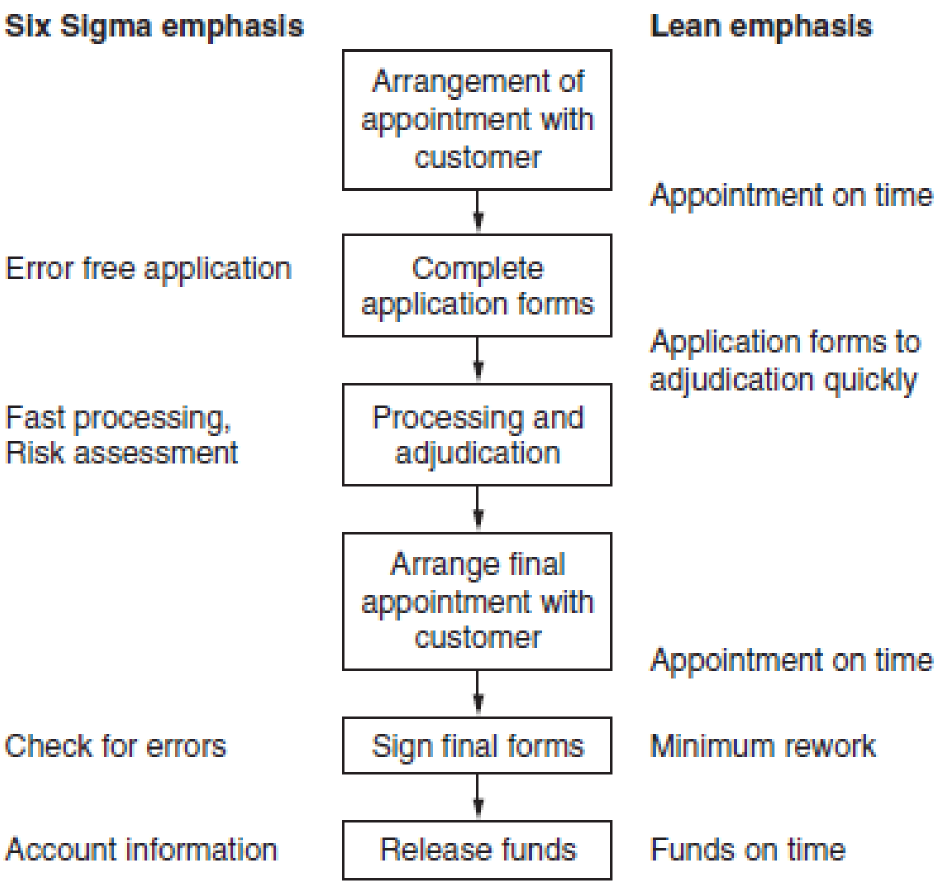

Figure 3

An example of Six Sigma and Lean for Mortgage Processing. (Muir, 2006, p. 12)

As we dig deeper we discover that "Lean and Six Sigma are perfectly matched to be used as one comprehensive approach uniting the key elements of both". Each one can gain from the other while both track the Six Sigma path of Define, Measure, Analyze, Improve and Control (DMAIC). The fusion of Lean and Six Sigma targets in exploiting every opportunity for development within every organization. While Six Sigma is controlled by specific individuals, Lean promotes the empowerment and cultivation of everyone within the organization to identify and eliminate all the non-value adding processes (Higgins, 2005).

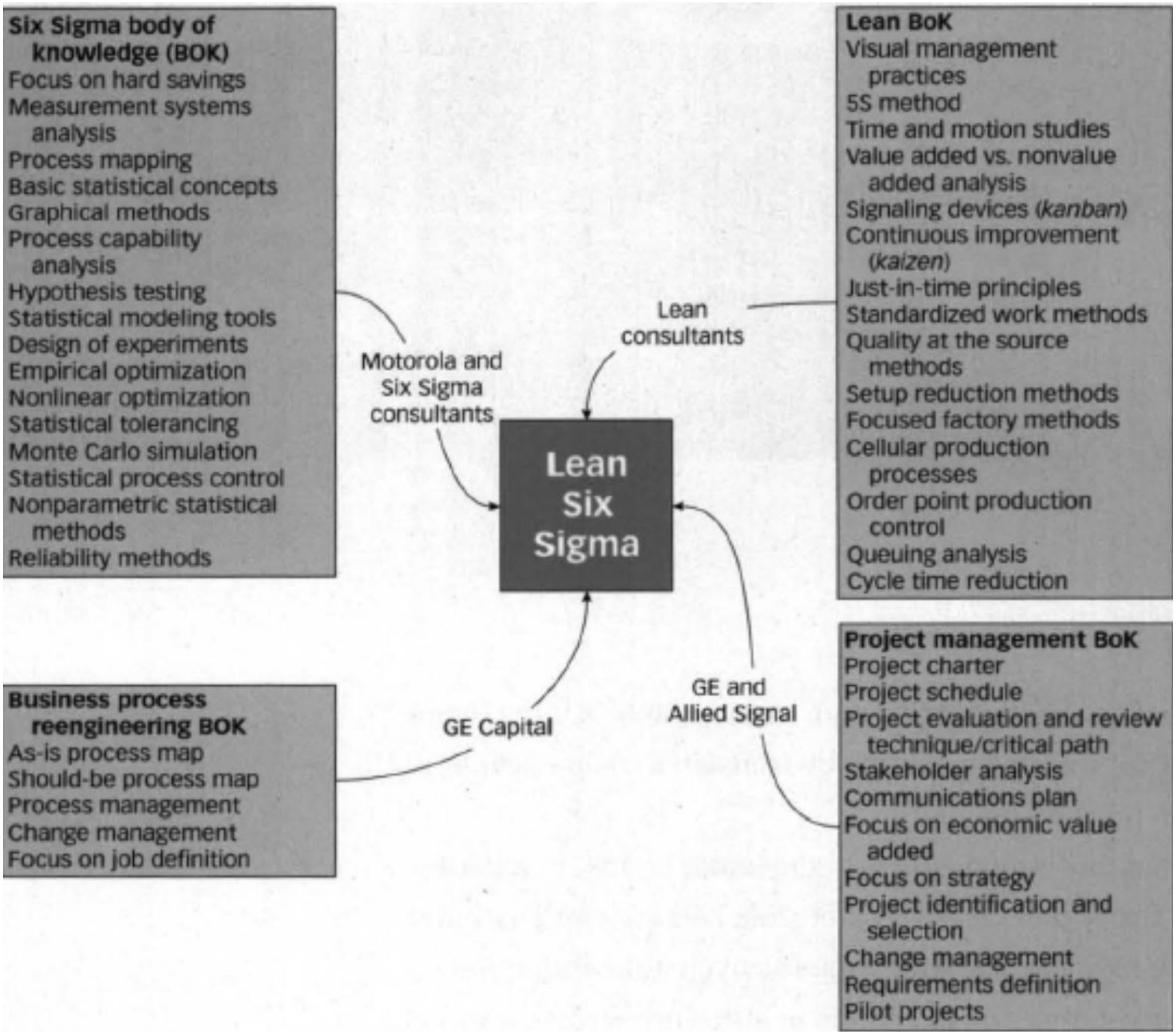

Figure 4

Lean Six Sigma constitutes of four BoKs. (Higgins, 2005)

The integration of the two approaches endeavors to create empowerment from the higher to the lower level process analysis stages. Employees are challenged to bare ownership of processes, provided they are given the needed drive and motivation. If we attempt to implement these two separately, the outcome will most possibly be a complete failure; because they one will constrain the other’s needs (Harrison, 2006). Again, it could even create two subcultures within the organization, competing for the same resources (Smith, 2003).

Researchers have reported that although both approaches have the same end objective, that is to achieve a high quality throughput of service or the product, they are also responsible for a plateau. The plateau is that after organizations have reached a satisfying level of quality they might “find it difficult to support the ongoing culture of continuous improvement” (Arnheiter & Maleyeff, 2005).

With the drive of overcoming this, the Lean approach must utilize targeted data (statistics) that will help in adopting a more scientific approach. In contrast; Six Sigma must adopt a broader and more systemic thinking, that considers the effects of waste on the system and therefore quality and variation. In *Figure 4* we have illustrated what we can gain from the fusion of the Lean and Six Sigma into a single framework and also the balance that we must reach in order to have an effective result (Arnheiter & Maleyeff, 2005).

The key concept for reaching a state of equilibrium, between the two approaches, is moving away from a dogmatic approach either direction. One extremity is becoming too lean and therefore inflexible in requests from the market and consequently directly impacting the value creation. The opposite extremity is to focus too much on minimizing variation, beyond customer requirements, and as a result we will waste valuable resources in the pursuit of “zero variation”. The golden rule is “creating satisfactory value from the customer’s viewpoint, so that market share is preserved, while at the same time reducing variation to acceptable levels so that lower costs sustained, while avoid over-engineering” (Pepper & Spedding, 2010).

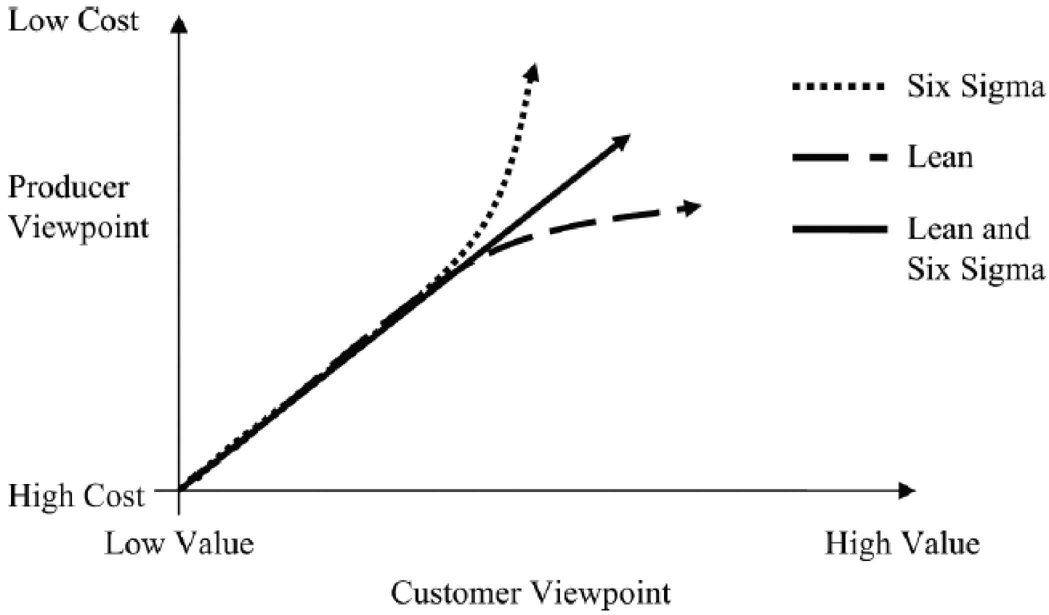

Figure 5

The competitive advantage of Lean, Six Sigma and Lean Six Sigma (Arnheiter & Maleyeff, 2005).

3.6 Lean Six Sigma toolbox

3.6.1 Pareto chart

The purpose of a Pareto chart is to identify those "vital few" areas that account for the largest frequency or relative frequency in a data log and separate those areas from the "trivial many". Dr. Joseph Juran discovered in the 1920s through his studies into Quality management that a few defects were responsible for the greater part of rejects. He has also found this very same norm could be applied to employee absenteeism, causes of accidents in a workplace, rework and many other management dynamics. Dr. Juran concluded that the Pareto principle had many applications. Some of them are the "80% of customer dissatisfaction stems from 20% defects, 80% of the wealth is in the hands of 20% of the people, 20% of customers account for 80% of a business” (Bass & Lawton, 2009). The 80/20 rule allows us to identify and focus on the approximately 20 percent of factors (that is, columns or categories) that account for approximately 80 percent of potential problems (Wedgwood , 2007).

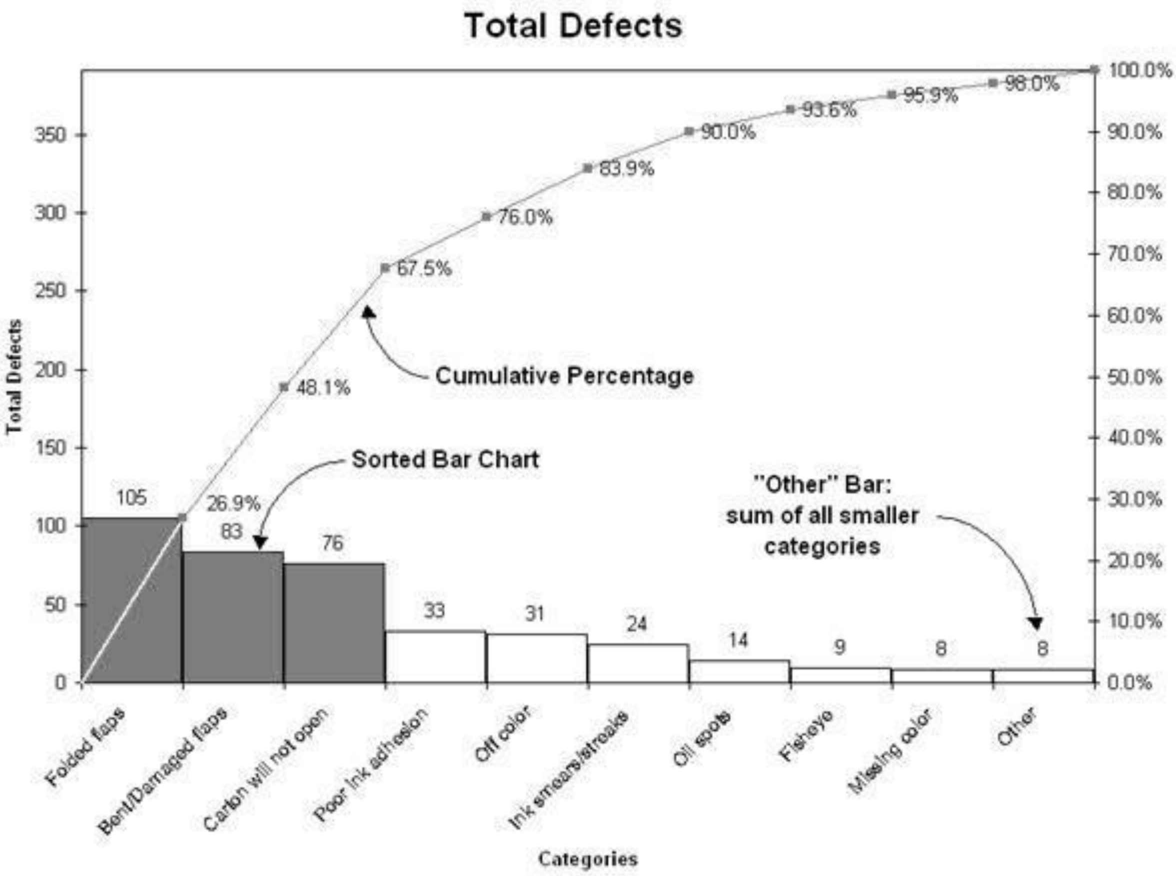

Figure 6

A Pareto chart sample.

Once we have gather the needed data; we rank in orderly manner the columns or categories of our data. The ranking is ordered from the highest frequency or relative frequency on to the lowest frequency or relative frequency. Then we prepare the graphic. We have to calculate and place on the graphic a relative frequency line above the data columns or categories. A relative frequency line can be calculated and placed above the data in a Pareto chart for quick assessment of the relative contribution made by each column or category (Borror, 2009).

3.6.2 Cause & Effect Matrix

The Cause & Effect Matrix is a powerful Lean Six Sigma tool which is used to prioritize potential causes by examining their relationship with the Critical To Quality (CTQ). Critical To Quality are all the elements that have a strong interconnection with the quality of a product or service; the ultimate judge for this is the customer.

All these elements are (CTQ) are placed on the top of the matrix and causes (or generally issues) are place along the left side. Every element (CTQ) is ranked in terms of importance. The relationship between the causes and elements (CTQ) are ranked. An overall score is calculated and the cause with the highest overall score should be addressed first because they will have the largest impact on the customer. It is obvious that this tool is customer oriented and aims for to raise the customer satisfaction levels.

The roadmap for a Cause & Effect Matrix is pretty simple in theory, but it is very important to to work effectively as a team to create something realistic and valuable. We start by listing the CTQs in the top columns of the matrix. We then rank and assign scores to each CTQ rendering its importance to the customer. Following is the enlisting of the causes, on the left side of the matrix. It is very important to determine the correlation between every cause and CTQ based on the strength of their relationship by giving a score. (For example 1 for weak up to 10 for strong) Finally we multiply the correlation scores with priority scores and add across for each cause. The results will give us a ranking on which issue we should address first.

Cause & Effect Matrix Form													
												Date:	06/26/07
ICT Team Goal: To reduce WO cycle time by 20%		Choose from: 1, 3, 7, 10 1 = Least Impact / 10 = Most Impact											
	Weighted by Importance:	5		7		3		10		1		
Item #	Process Input	Output: Good WO Flow		Output: Proper Capacity-Demand Planning		Output: Reduced Que Time		Output: Data Integrity		Output: Other?		Most Important
1	How parts are stocked	3	15	1	7	1	3	7	70		0	95
2	Standardized kitting	3	15	1	7	1	3	7	70		0	95
3	Knowledge of capacity for each area	7	35	10	70	1	3	7	70		0	178
4	Experienced / educated operators	10	50	7	49	3	9	7	70		0	178
5	Small batch sizes	10	50	3	21	1	3	1	10		0	84
6	One piece flow (Cell Manf.)	1	5	1	7	10	30	1	10		0	52
7	Predictable demand schedule	7	35	10	70	7	21	1	10		0	136
8	Using a global capacity - demand tool	7	35	10	70	3	9	3	30		0	144
9	Proper resources for material movement	7	35	3	21	3	9	1	10		0	75
10	Accommodating for people on vacation	7	35	10	70	7	21	1	10		0	136

Table 1

Cause & Effect Matrix sample.

3.6.3 Failure Mode and Effect Analysis

The Failure Mode and Effects Analysis (FMEA) is another Lean Six Sigma tool. It sounds maybe more complicated than it really is. At its core, the FMEA simply asks the project manager, as well as the project team, to brainstorm about what may go, or have gone, wrong in the implementation of a project. The FMEA will be populated with all the possible effects, while respecting the operational implementation (Goldsby & Martichenko, 2005). Three are the critical factors that must be rated for each effect, these are:

- The likelihood of occurrence. With 1 = “Not likely” and 10 = “Almost certain”.
- The ability to detectability. With 1 = “Likely to detect” and 10 = “Very unlikely to detect”.

- The severity of the effect. With 1 = “Little impact” and 10 = “Extreme impact”, such as personal injury or high financial loss.

FMEA tables are gaining increasing popularity as a way encountering a variety of issues from manufacturing to Research & Development. That is why we have various types of FMEA like the Market, Design, Project, and Process (Wedgwood , 2007).

Process/Product
Failure Mode and Effects Analysis Form (FMEA)

Process or Product Name		Prepared by:	Page ___ of ___
Responsible		FMEA Date (Orig): _____ (Rev): _____	

Process Step/ Input	Potential Failure Mode	Potential Failure Effects	Severity	Potential Causes	Occurrence	Current Controls	Detection	RPN	Action Recom-mended	Respon-sible	Actions Taken	Severity	Occurrence	Detection	RPN
What is the process step & Input under investi-gation?	In what ways does the Key Input go wrong?	What is the impact on the Key Output Variables (Customer Require-ments)?		What causes the Key Input to go wrong?		What are the existing controls & procedures (inspection & test) that prevent either the cause or Failure Mode?			What are the actions for reducing the occurrence of the cause or improving detection?		What are the completed actions taken with the re-calculated RPN?				

Identify Failure Modes and Their Effects — Identify Causes and Failure Modes and Controls — Prioritize — Determine and Assess Actions

Table 2

A FMEA form sample (Michael, 2003).

4. METHODOLOGIES AND PROCEDURES USED IN THE STUDY

4.1 Pulsar S.A. – The Case Study

PULSAR S.A. provides innovative Data Center (DC) outsourcing services. The company is involved in several private Neutral World-Class Data Center projects, which are developed under the supervision of the Data Center Infrastructure Integration Department and operated from the Operations Department. PULSAR provides a variety of services and solutions to its customers. Reduces their overall costs and risks, while increasing the availability of their mission critical systems and applications, consequently customers maintain their autonomy and independence.

By implementing a Quality Management System (QMS) under ISO 9001:2008, PULSAR intends to become a leading neutral Data Center Outsourcing and Infrastructure Integration services company in the East Europe, targeting public organizations, large national and multinational corporations and businesses active in the Information Technologies (IT) and telecommunications industries.

The Quality Management System is regularly reviewed, updated and amended on a regular basis by the Quality Manager in conjunction with the management and the personnel of PULSAR. In addition, the quality policy is constantly communicated throughout the organization and the company is committed to the continuous training and development of its personnel both technically as well as in quality improvement matters. In conclusion, PULSAR tries to build quality into every service and solution, aiming in fulfilling the needs and requirements of its customers and continuously improve its organization.

4.2 Data Center project management & turn-key projects

PULSAR manages from turn-key to customized Data Center projects. The company is manned with skilled engineers that are capable of project, as well as, construction management. Pulsar can undertake any project or part of a project that involves:

- Power supply and distribution (Uninterruptable Power Supply units, Generators, Medium & Low Voltage, distribution panels, etc.).
- Environmental conditions monitoring and control (Closed Control Units, Chillers, Hot Aisle Containment System, temperature/humidity sensors etc.)
- Fire Detection & Suppression (smoke detectors, inergen gas, sprinklers, etc.)
- Access Control & CCTV (cameras, monitoring software, card readers, etc.)
- Special racks and related equipment (Power Distribution Units, Keyboard Video Mouse unit, etc.)
- Structured Cabling (fiber optic cabling, UTP cabling)

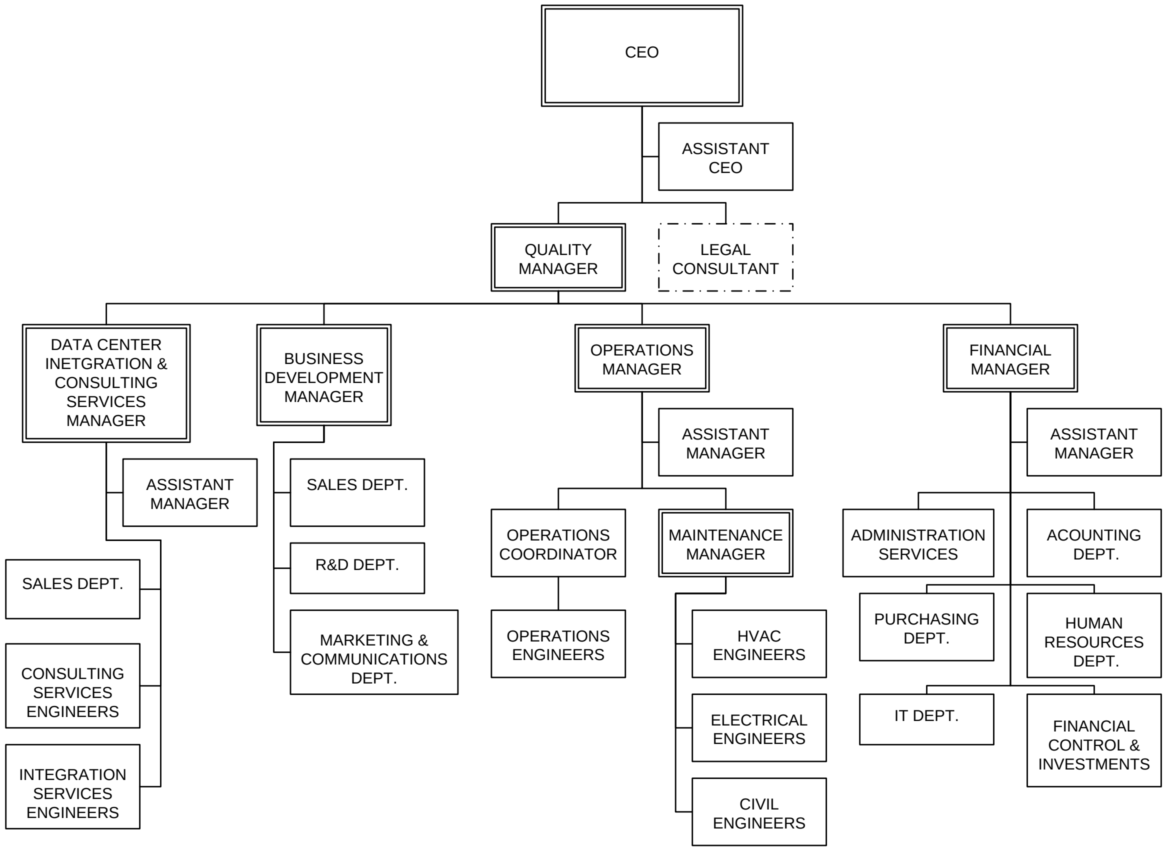

Figure 7

PULSAR's Organizational Chart.

In order to enhance its services, it has partnered with and strategically aligned to some of the leading global vendors for Data Center infrastructure equipment. It is very important to keep in mind that a Data Center project is considered a critical facility project. Since a Data Center has a minimum tolerance to outages and equipment faults, the availability indicators are very important. Most of the times surgical accuracy and emphasis in detail is needed; from construction all the way to operation. PULSAR is able to deliver up to 99,999% availability via world class service level agreements that are fully aligned with international regulatory frameworks such as Basel II, Sarbanes-Oxley, BS-7799.

Figure 8

Inside a Data Center; rows consisting of racks full of servers.

4.3 PULSAR's flow of processes

If we want to understand the way that PULSAR manages a project, apart from the organizational chart, we have to look into the way that utilizes its resources. Additionally we have to examine how this organization handles issues, when they occur, as well as how it implements the five project phases (Initiation, Planning, Execution, Monitoring and Controlling, Closing). (PMI, 2008). The following flow chart, (*Figure 9*) does not offer details, by will definitely provide a walkthrough of the project process flow. This will be especially helpful when we attempt to find the weaknesses and the potential bottlenecks of the flow. The Lean Six Sigma toolbox will provide us the techniques to analyze the situation holistically and proceed in resolving these issues.

4.4 Implementation of the Lean Six Sigma tools.

Now that we are more familiar with the structure and the industry of this organization we can proceed with the collection of data. The data we have collected was through by interviewing with PULSAR's employees, one by one. The focal point of these meetings is to trace the issues that have become barricades on the road to higher efficiency levels.

After we have collected the data we needed the implementation of Lean Six Sigma tools started. Our first stop was the Pareto chart where we had the chance to narrow down the issues that were most to urgent to address. Then we continued with the Cause & Effect Matrix in order to prioritize which issue we should address first, the ranking was done with customer oriented criteria. Finally, we have analyzed the current status and provided actions and strategies to be applied. At that point PULSAR has to review the tables provided by the FMEA, we have created, and decide for further action in order to complete this procedure.

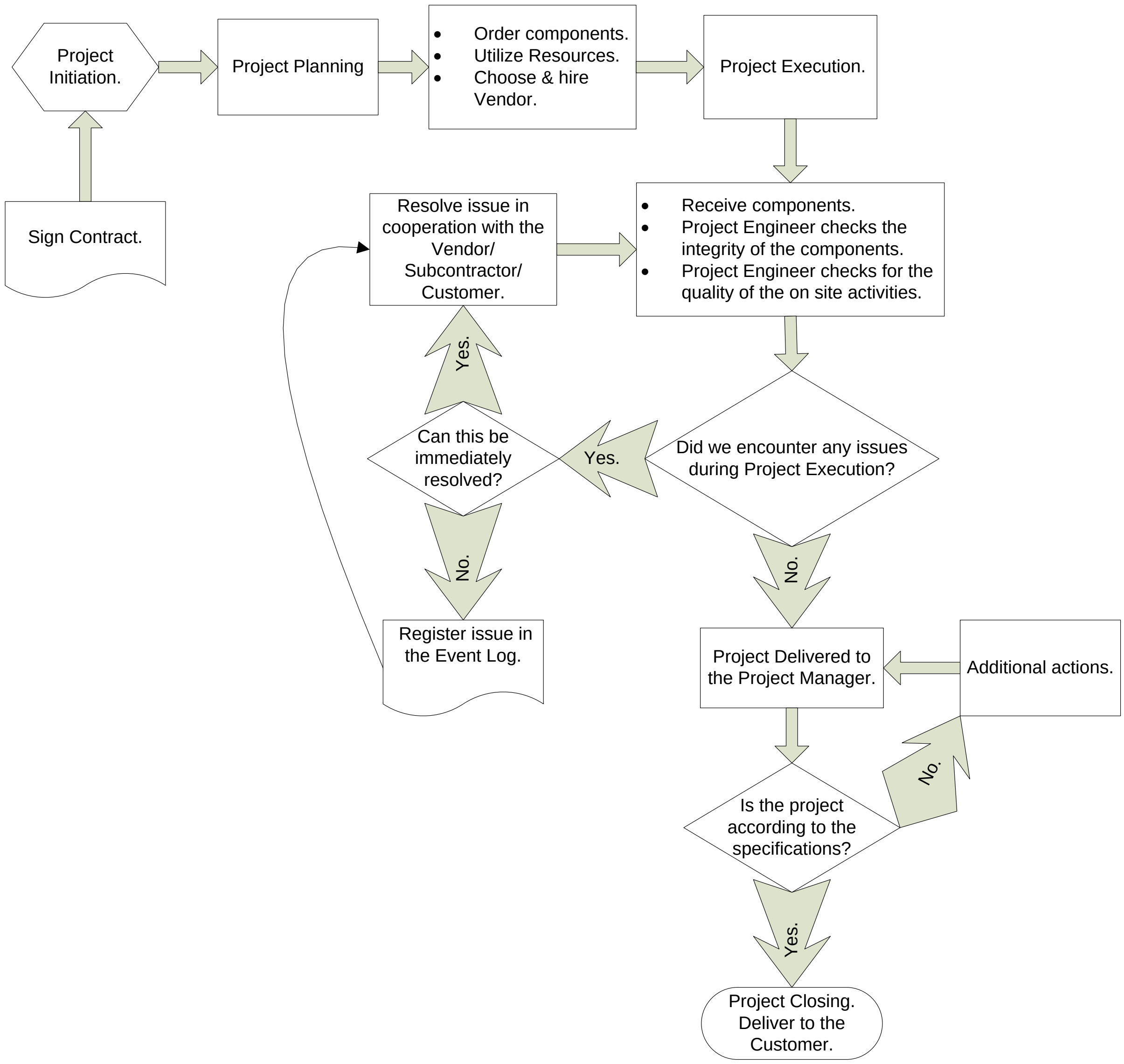

Figure 9

The project flow chart.

5. RESULTS

5.1 PULSAR's Pareto Chart

The first step that we made towards implementing Lean Six Sigma was to gather data from PULSAR's employees. From the total of fifty employees we managed to interview almost half of them. In this process we didn't use a specific questionnaire; because this way it was easier to elicit the information we needed. It was also very helpful the fact that we had established personal relationships with some of the employees and thus they provided us access into their data logs. After certain data processing and the use of statistical software (Minitab v15) the results are gathered in *Table 3.* As we can see the interviews were focused on issues that this organization has encountered through the last ten years, counting more than 100 projects.

Table 3

Table with the causes of project issues and their frequency.

No.	Causes	Frequency	%	Cummulative %
1	Customer Scope Creeps.	62,50	17,38%	*
2	Poor PM knowledge (PM Team).	42,50	11,82%	29,20%
3	Customer inconsistent with his payments.	40,00	11,13%	40,33%
4	Customer unable to provide important data.	35,00	9,73%	50,06%
5	Unrealistic customer demands.	25,00	6,95%	57,02%
6	Lack of user involvement.	22,50	6,26%	63,27%
7	Vendor issues.	17,50	4,87%	68,14%
8	Subco. quality related issues.	17,30	4,81%	72,95%

9	Subco. unavailable.	16,00	4,45%	77,40%
10	Poor communication between departments.	14,00	3,89%	81,30%
11	Poor planning and execution.	13,50	3,75%	85,05%
12	Program Management issues.	13,00	3,62%	88,67%
13	Subco. poor tech background.	12,50	3,48%	92,14%
14	Complex pricing processes.	12,00	3,34%	95,48%
15	Communication issues with the customer.	10,00	2,78%	98,26%
16	Force majeure.	6,25	1,74%	100,00%

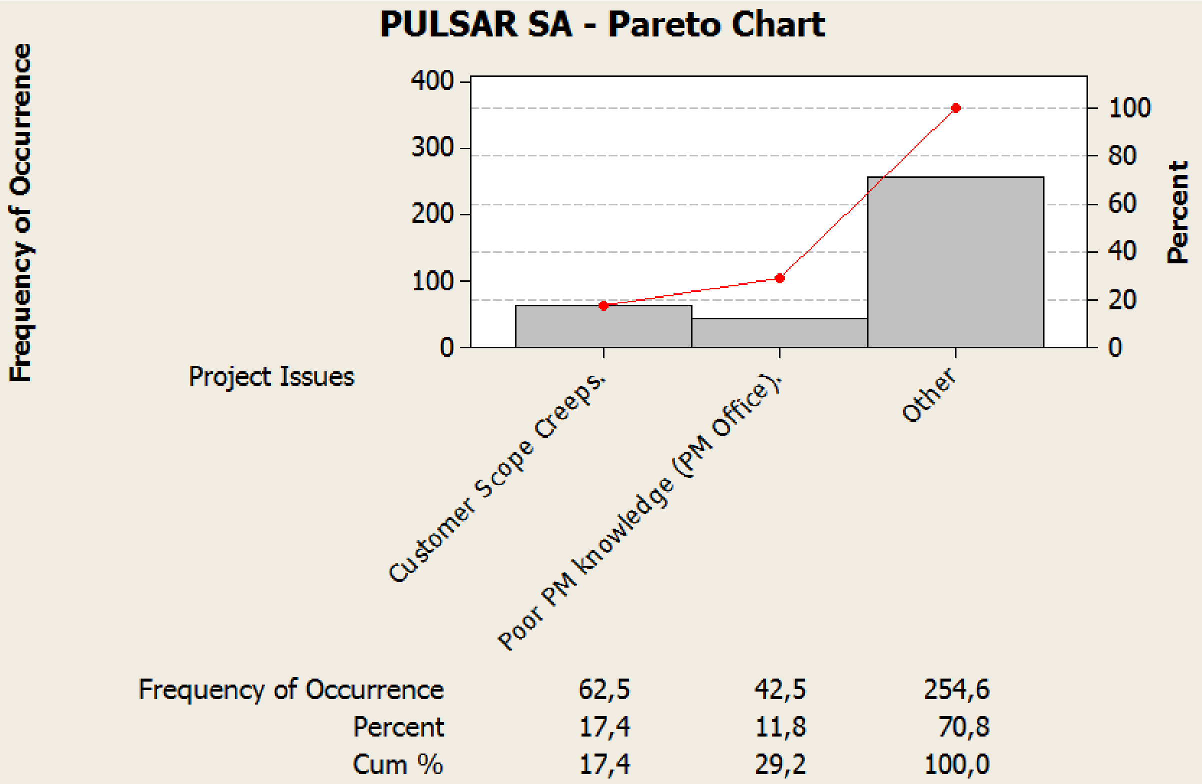

Figure 10

PULSAR's Pareto Chart.

After considering the 80/20 rule we are able to narrow down the critical causes in just two. According to the theory these two, that have a total cumulative of 29,2%, are the reason for 80% of the problems we daily encounter in PULSAR's projects.

5.2 PULSAR's Cause & Effect Matrix

Following our strategy, in implementing Lean Six Sigma, we use the Cause and Effect Matrix which will help us prioritize the causes, which were indicated by the Pareto chart and should be addressed immediately.

5.3 PULSAR's Failure Mode & Effect Analysis

After a successful implementation of the FMEA method we have created a rather big table. For the sake of better understanding as well as better readability of the table, we decided to split it in two parts. It is very important to mention that the Potential Failure Effects (KPOVs) are in two distinct groups, the "Customer Scope Creeps" and the "Poor PM knowledge" and they do not relate with the rest of the table in any other way.

Table 4

Cause & Effect Matrix for the PULSAR case.

Cause & Effect Matrix - PULSAR SA		**1 = Least Impact / 10 = Most Impact**									
	Weighted by Importance:	**8**		**10**		**6**		**4**			
Item #	**Issues.**	Output: *On time delivery.*		Output: *Within budget.*		Output: *Quality of the product.*		Output: *Progress reports.*		**Most Important**	**Top**
1	Customer Scope Creeps.	10	**80**	8	**80**	2	**12**	4	**16**	**172**	**1**
2	Poor PM knowledge (PM Office).	6	**48**	6	**60**	8	**48**	10	**40**	**156**	**2**

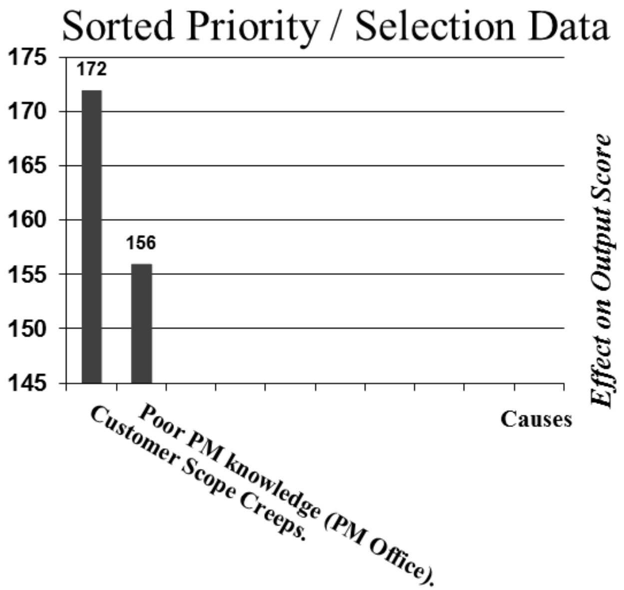

Table 5

The FMEA table (Part I)

<table>
<tr><th>#</th><th>Process Function (Step)</th><th>Potential Failure Modes.</th><th>Potential Causes of Failure (KPIVs)</th><th>Current Process Controls</th><th>Potential Failure Effects (KPOVs)</th></tr>
<tr><td>1</td><td>Customer Scope Creeps.</td><td>Additional manpower needed to complete the project.</td><td>Lack of proper initial identification of what is needed to complete the project.</td><td>Design engineers.</td><td rowspan="3"><u>Customer Scope Creeps.</u>
Program Manageement problems.
Employees have to work overtime.
Resources aren't available.
Additional costs that can't be reimburshed.</td></tr>
<tr><td>2</td><td>Customer Scope Creeps.</td><td>Additional time needed to complete the project.</td><td>Poor Change Management procedures/policies.</td><td>Project manager.</td></tr>
<tr><td>3</td><td>Poor PM knowledge (PMO).</td><td>Different expectations by the Project Manager/PMO/Customer.</td><td>Poor communincation between the stakeholders.
Vague goals/expectation.</td><td>Project manager.
Quality manager.</td></tr>
<tr><td>4</td><td>Poor PM knowledge (PMO).</td><td>Communication management rework, lack of templates/processes/procedures.</td><td>Poor or no communication plan.</td><td>Project manager.
Quality manager.</td><td rowspan="7"><u>Poor PM knowledge (PMO).</u>
Employees have to work overtime.
Resources aren't available.
Problems with Quality Controll and Quality Assurance.
Unable to provided the expectede quality.
Difficulty to manage the project.
Conflicts, csutomer unhappy, PMO stressful envoronment.
Miscommunication.
Information do not flow / flow on the wrong paths.</td></tr>
<tr><td>5</td><td>Poor PM knowledge (PMO).</td><td>Quality Management rework, lack of templates/processes/procedures.</td><td>Lack of proper Quality manageemnt training.</td><td>Quality manager.</td></tr>
<tr><td>6</td><td>Poor PM knowledge (PMO).</td><td>Need for rescheduling.</td><td>Poor schedulling/poor estimation processes.
Poor communication between on-site/design engineers.</td><td>Design engineers.
Project engineer.
Project manager</td></tr>
<tr><td>7</td><td>Poor PM knowledge (PMO).</td><td>Need to redefine project assumptions, risks, organization and overall approach.</td><td>Poor communication in the PMO.
Lack of essential project management processes.</td><td>Project manager.
Quality manager.</td></tr>
<tr><td>8</td><td>Poor PM knowledge (PMO).</td><td>People are impacted by the project, last-minute surprises.</td><td>Poor interdepartmntal communication.</td><td>Project manager.
Quality manager.</td></tr>
<tr><td>9</td><td>Customer Scope Creeps.</td><td>Additional money needed to complete the project.</td><td>Poor communiaction between customer/organization.
Disingenuous customer/Weak project manager.</td><td>Project manager.
Quality manager.</td></tr>
<tr><td>10</td><td>Poor PM knowledge (PMO).</td><td>No one knows what the state of the project is exactly (cost/schedule).</td><td>Poor monitoring and controlling procedures.
No project management software.</td><td>Project manager.
Quality manager.</td></tr>
</table>

Table 6

The FMEA table (Part II)

#	Recommend Actions	Responsible Person & Target Date	Taken Actions	SEV	OCC	DET	RPN
1	Establish an effective bilateral communication between design & project engineers.	Design engineers.		9	10	6	540
2	Create Change Management processes and procedures and communicate them, inadvance, with the customer.	Project manager.		8	6	9	432
3	Project Management education. Follow/review diligently the Communication plan.	Project manager. Quality manager.		8	5	10	400
4	Project Management education. Establish Project Communication Management.	Project manager. Quality manager.		5	8	10	400
5	Project Management education. Establish Project Communication Management.	Quality manager.		5	9	8	360
6	Project Management education. Impove/review poor schedulling/poor estimation processes.	Design engineers. Project engineer. Project manager		7	7	7	343
7	Project Management education. Establish and communiacte PMO ground rules. Make the necessary additions to achieve this (add processes).	Project manager. Quality manager.		8	3	8	192
8	Project Management education. Follow/review diligently the Communication plan. Establish and communiacte PMO ground rules.	Project manager. Quality manager.		6	5	6	180
9	Enhance the communication with the customer. Invigorate the Contract management department.	Project manager. Quality manager.		10	4	4	160
10	Project Management education. Review the monitoring and controlling processes combine them with the use of Project Management software.	Project manager. Quality manager.		7	2	6	84

6. DISCUSSION – CONCLUSIONS – RECOMMENDATIONS

Having an overview of the Lean Six Sigma approach as well as the PULSAR's structure, as an organization, we can now make some recommendations. The data, provided by the organization, along with the analysis we made gave us the ability to look in more depth the issues to be resolved. Prior to referring to those issues; we can safely state at this point that PULSAR should definitely adopt some Lean Six Sigma tools.

Organizations like PULSAR that construct Data Centers, face two great challenges in every project. The first is "zero tolerance for downtime"; this means that facilities like these cannot afford the luxury of downtime (server shutdown). This is because these servers support banking transactions, top secret data, telecommunications, energy distribution and many other critical applications. We easily understand that if these systems do not operate we will have serious problems. The second is oversizing; by this term we mean the tendency of constructing a site much bigger than our current or future needs. This is a common pitfall that engineers and owners encounter. The reason behind this is that, it is easier to create a bigger Data Center in advance than expanding a small one according to your needs. While this option is easier, it will eventually cost more money, in terms of higher energy consumption and bigger investment of assets.

Here is where Lean Six Sigma can take the lead. Lean Six Sigma can provide a higher quality product that will offer the customer/owner the ability to increase the levels of availability of his Data Canter. This is because the operation as well as the maintenance, of the site, will have greater efficiency levels than in any other case. Since Lean Six Sigma is oriented in providing what is really needed, without the hidden wastes, will help us avoid the pitfall of oversizing by establishing effective communication and maturity in planning processes.

In order to achieve all these a few simple suggestion might prove very helpful. Firstly the Quality manager should get official training sessions from professionals. Those “Black-belts” will also support this transitional phase as consultants. Afterwards all the employees should be communicated with the Lean concepts. We have seen other organizations which exhibit resistance in changing and adopting new approaches. The key here is communication; we must make the whole organization share the vision of a leaner tomorrow. The second important thing is building trust throughout and between every department. This is crucial in introducing Lean Six Sigma into a traditionally managed company. Finally very important is to find vendors and subcontractors that are familiar with Lean Six Sigma and are able to understand its processes thus helping in creating a common ground of communication.

Furthermore everybody at the Project Management Office should get professional training and the use of project management software should be authorized. This way the impact of other issues will be extinct or reduced significantly because; as we observe the environment of this organization, microcosmically and macrocosmically, we conclude that everything is systemically linked. This means that with the solid foundation we will build problems will be resolved simultaneously, simply because they were not the cause but just the effect of poor management.

Finally we have to mention that the FMEA tool is not fully utilized as it needs specific actions (*Taken Action*, column). Managers with the help of Lean Six Sigma champions are responsible for designing and implementing the identified corrective actions, according to a predefined schedule that will assist in the monitoring of the overall progress.

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