Abstract #: 025-0155

Abstract Title: **Effectiveness of Lean Management tools: Structured Problem Solving Process at Automotive Industry**

Lebanese American University

Dr Raed EL-Khalil

Assistant Professor

School of Business

POMS 23rd Annual Conference

Chicago, Illinois, U.S.A

April 20 to April 23, 2012

Abstract

Lean Management, Lean Manufacturing, Toyota Production System (TPS) or Lean production is a set of tools and techniques which focus on eliminating waste for the objective of improving customer value. The lean techniques are designed to support quality improvement, cost and time reduction. The purpose of this paper is to present the practical problem solving process (PPSP) and its effectiveness at one of the Big Three (General Motors, Ford Motor, and Chrysler) companies in North America. The paper focused on 6 assembly plants, where 138 problem solving forms were obtained from each plant, in addition to a PPSP survey which was administrated to 600 employees at those facilities. The result revealed that, the PPSP is a very effective tool and that promises significant cost reduction or avoidance ($7.5 million/annually). Recommendations were presented to the company to provide more commitment to the lean

process, lean training, and to create a common lean database that can be utilized by management in order to be proactive in implementing lean tools such as the PPSP.

Keywords: Lean Management, Practical problem solving process (PPSP), Big Three (Chrysler LLC, GM, and Ford)

1. Introduction

The lean management process provides tools and methods that focus on improving quality and reducing lead time and cost (EL-Khalil, 2011). The Lean management process and or the Toyota production system (TPS) were originally developed by Toyota motors and were presented to the world in 1990 (Womack et al, 1990). The automotive industry (Big Three) in North America started adopting the lean management process at the end of the 20th century (Liker, 2004). Driven by the lean process, companies like Chrysler LLC were able to improve their manpower efficiency by 35% and reduced their manufacturing cost by 18.5% between 2002 and 2009 (EL-Khalil, 2009), others like Ford Motor Company (2006-2008) improved their manpower efficiency and effectiveness (product development time) by 25% (EL-Khalil, 2009). Womack and Jones (1996) in *Lean thinking* have stressed that multiple organizations tried to implement the Toyota lean management process, but did not achieve the same efficiency results that Toyota did because the adoption was selective and not comprehensive. Liker and Morgan (2006) and Liker (2004) discussed that the lean management system will only work to its full

extent if and only if it was adopted as a way of living "a culture" and that the lean techniques and tools cannot be selected based on convenience by the managers. In order to successfully implement the lean management process, organizations should apply it "regularly and consistently" (Liker 2004).

The Lean management process is divided into several categories: Process management tools, quality tools, equipment tools, material tools and production tools (Wilson, 2010). The process management category includes a set of tools that focuses on the deployment of business plans in addition to problem solving and reporting tools (Arnheiter and Maleyeff, 2005).

A "problem" represents a discrepancy between existing standard/expectation and the present or actual condition. The 'problem solving' process represent a systematic approach to improve a deviation from a standard or expectation (Arnheiter and Maleyeff, 2005). A deviation from standard can arise at any stage during design, assembly, and manufacturing and if the problem is not addressed properly and resolved it will directly impact the quality of the product thus impacting the organizational efficiency and effectiveness (EL-Khalil, 2009).

The implementation of the problem solving process varies between companies and or organizations. Typically automotive companies have relied on "benchmarking" processes based on the concept that if the process makes a certain company successful, then it is the best practice. The automotive industry in North America and specifically the Big Three typically utilized the Shewhart Deming Cycle (Lean Manufacturing), Plan Do Check Act (PDCA) and six sigma Define-Measure-Analyze-Improve-Control (DMAIC) processes as common approaches for problem solving (Liker and Meir, 2007).

Driven by the fact that the quality department is the liaison between the customer (product or service) concerns and the organization, the lead role in the problem solving process was assigned by default to the quality department (Marksberry et al, 2010). The main concern with this approach is that the quality departments have to investigate each issue and typically managers or concerned parties don't want to report or expose "inadequate" information and or problems in their related areas to the customer. Therefore, some of these issues will not be resolved and there is a very high probability that those issues will be repeated again. A very reliable approach to assigning the problem solving process to the quality department is to assign the issues to their related functions (Marksberry et al, 2010). The team leader, supervisor, manager, operation manager, coordinator, and engineer responsible for the zone or area where the problem occurred will take the lead in the problem solving process. This concept is based on the reasoning that this individual or team is the primary concerned party and the expert in the area or work zone for resolving the problem (Liker, 2004). Toyota manufacturing introduced a practical problem solving process (PPSP) as part of its TPS tools; this PPSP is a systematic process of accomplishing a robust solution for a discrepancy or problem (Marksberry et al, 2010). The Toyota PPSP is based on the PDCA continuous improvement process and it follows a structured sequence of 8-steps that a problem solver must conduct in order to identify and eventually eliminate a problem, as illustrated in Table 1 (Zhang and Liang, 2010).

Table 1 The structured problem solving process sequence at Toyota

Step	Description	Details
1	Clarify the problem	What is the Ultimate goal of your work
		What is the ideal situation your work
		What is the current situation of your work
		What is the gap between current and ideal condition or situation
2	Break down the problem	What is the detail break down of the problem
		What is the symptoms or problem to purpose
		What is the point of cause (POC)

3	Target setting	Make a commitment
		What is the measurable, concerns and targets
4	Root cause analysis	What is the causes of this problem
		what are the 5 whys for this problem
		What is the specific root cause
5	Develop countermeasure	What is the list of possible countermeasure (as much as possible)
		What are the most practical and effective countermeasures
		Get consensus with the team on countermeasures
		What is the action plan based on the team consensus
6	See countermeasures through	Implement countermeasures
		Share progress, report progress
7	Monitor both results and processes	Evaluate results
		Understand factors behind success or failure
8	Standardize successful processes	Structure the successful processes
		Share the new precedent
		Implement continuous improvement

Several companies have adopted the PPSP during the past decade, but they failed to achieve the success which Toyota was able to accomplish (Liker, 2004). The main reason is that the 8 steps process should be applied as a systematic way of thinking instead of a template or a document that needs to be completed (Marksberry et al, 2010).

This paper attempt to investigate the effectiveness of the PPSP utilized at one of the Big Three companies in North America. The paper will start by investigating the PPSP utilized by the company, surveying the level of training given to employees on the process and it will also present a sample of the actual PPS sheet/form utilized. The paper will utilize 138 SPPS sheets collected over a year from 6 different facilities. Those scorecards (SQDCME) reflect the following issues: 6 safety (S), 6 quality (Q), 5 delivery (D), 2 cost (C), 2 moral (M), and 2 environment (E) problems. The SQDCME issues are similar from description perspective but they don't necessarily reflect/report the same problem causes or symptoms. For example in safety from a description perspective, the 6 issues could relate to a common result or injury that

caused the employee a temporary disability, but the symptoms and causes could be different. The PPSP sheets utilized will be investigated on the following bases:

1- Cost avoidance achieved.
2- Commonality of cases and repetition of issues across the different plant and or within the same facility.
3- Failure points at any step or stage in the PPSP (PPS sheet).

Lastly, the paper will present lessons learned and recommendations for improving and insuring better PPSP implementation at the company studied

2. Literature review

Original problem solving work and or application can be traced back to the Egyptians and Romans era (Sternberg, 1986). This work focused on human problem solving, that this "higher-order cognitive process" that requires the "modulation and control of more routine or fundamental skills" (Hepner et al, 2004). The process of problem solving has evolved in the past century to encompass all aspects of life, some of the areas involved are: decision making, scientific induction, artificial intelligence, creative thinking, Invention, general management, learning and processing theory (Marksberry et al, 2010). There are four approaches to the development of problem solving skills and or problem solving frame work (Marksberry et al, 2010):

1- Scientific inquiry (Dewey, 1910), which focuses on cognitive thinking that is based on speed, accuracy and logic. The focus is to create a single solution and test the hypothesis.

2- Creative thinking: focuses on generating multiple solutions or answers to a problem. It's also known as flexible thinking it extracts ideas from different sources.
3- Heuristic approach: focuses on the mechanics of the process, the process is defined as "to cause the best change in a poorly understood situation with-in available resources" (Koen, 1985).
4- Instructional theory: also known as guided discovery and is defined as the study of facilitation of human learning through instruction (Marksberry et al, 2010).

Problem solving is defined as "self-directed cognitive behavioral process by which a person attempts to identify or discover effective or adaptive solutions for specific problem" (Hayes, 1981). The process of solving a problem is conducted for the purpose of transforming a certain undesirable condition to a desirable result and or goal. Achieving the desirable goal or solution will require certain actions as detailed by the following steps: defining the nature of the problem, potential causes of a current state, countermeasure for containment, solution to the problem, and following up with the solution (Runarsson 2001).

The ability to solve a problem is driven by the ability to:

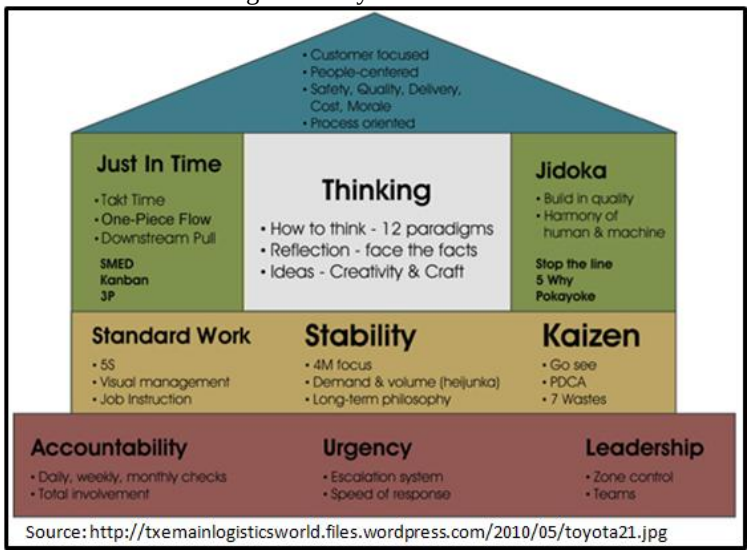
1- Detail the description of the current problem or situation,
2- Identify the point of cause, location of the problem,
3- Provide a vehicle to drive the change toward the desirable solution,
4- Monitor and follow up in order to insure goals are achieved.

While the content is similar, the number of steps taken by the problem solver to resolve a discrepancy or a problem varies. Poyla (1957) described the process as a 4 step sequence: 1) understanding the problem, 2) devising a plan, 3) carrying out the plan, and 4) looking back, others like Hayes (1981) described a sequence of 6 steps: 1) find the problem, 2) represent the

problem, 3) plan a solution, 4) implement plan, 5) evaluate the solution, and 6) review and assess gains. The main difference between the two authors is that Hayes broke down the fourth step given by Poyla to two stages, and that will allow the solver to dig deeper into creating a robust plan.

Motivated by its goal to be the leader in quality and process improvement, Toyota Motors introduced the lean management process. This lean management process includes multiple tools and techniques that focus on improving quality and eliminating waste, as illustrated in Figure 1. The structured practical problem solving process (PPSP) or methodology is one of those tools utilized. Toyota Motors was able to become one of the top 2 automotive companies in the world within 3 decades after the implementation of the lean process (EL-Khalil, 2009). Liker and Morgan (2006), Heppner et al (2004), and Mann (2005) refer Toyota's success to its intrinsic characteristics of a lean process that focus on finding the root cause of the problem and resolving it while ensuring it will never appear again.

Figure 1 Toyota TPS Tools



The Toyota PPSP is based on the PDCA cycle and continuous improvement process (Bicheno, 2008). The techniques of the TPS are designed to support each other, for example in order to implement the PPSP process for a specific station or problem, management has to insure they implement the 5's and waste illumination (7 waste) techniques for that station before trying to find a solution for the problem (EL-Khalil, 2009). The Toyota PPSP combines scientific methods with solver hands on experience (Liker and Morgan, 2006). What makes Toyota PPSP unique is the following:

1- Locating the point of cause (PoC) by machine by station. The process tracks back along the assembly line, checking each station (one by one), until reaching the station where the problem originated.
2- Short and long term solution implementation and tracking.
3- The 5 why cause and effect analysis.

The case and effect analysis (5 Why) present a fundamental shift in PPSP's way of thinking (Marksberry et al, 2010). For example if the problem started because a robot stopped in the middle of its cycle, a solver would ask the first why the problem happened and the answer could be: because a fuse was blown, then the solver would ask why again and the answer could be: that there was a circuit overload, the why's will continue until you reach an answer that in most cases require a simple solution such as changing a filter on the robot oil system. This process of digging deeper into the root cause, if addressed properly will resolve the problem and prevent reoccurrence.

Toyota's implementation of lean management process is driven from the bottom up, it starts with the line technicians and it drives the process to the upper level of the organization (Marksberry et al, 2010). All employees are trained (management and technicians) on applying the lean tools

(such as PPSP). The management plays the role of supporting teams and team members, and is assigned to train the employees on utilizing the lean management process including the PPSP. Toyota assigns the responsibility of a problem solving to the team in the impacted zone or department. Each department have multiple teams (typically one per zone) and the team for each zone consist of technicians, engineers, supervisors, managers and other support staff. Each team typically is led by the zone supervisor or technician team leader. The functional team will complete the PPSP as a team and assign tasks to resolve the problem (based on team members consent). The successful implementation of the process is based on the ability to assign the required tasks and or solutions to the proper personal (experts) within their area (EL-Khalil, 2009). According to the Toyota Vice Chairman Fujio Cho, the success of Toyota is driven by "integrating all the elements together into a system. It must be practiced every day in a very consistent manner not in spurts" (Liker and Morgan, 2006).

The TPS has steadily been producing products with high quality, faster production time, and at a lower cost than competitors. In addition, the TPS provided the company (Toyota) with the ability to produce a wider range of products efficiently based on customer's demand fluctuation. This success achieved by Toyota is attributed to its TPS that pushed the competition to investigate and adopt or attempt to adopt it. In order to compete in the automotive market, the Big Three invested heavily in the lean management process (Liker and Morgan, 2006). But the improvements achieved by those companies (Big Three) did not achieve their full potentials. For example, the J.D. Power survey for initial quality is dominated by Toyota since 2001, with 10 vehicles in the first place. Also, the ability of Toyota to bring in new products to the market (Design to production) is 12 month in comparison to the Big Three at 20 to 30 month (Liker and Morgan, 2006).

3. Research Approach

The overall approach in this analysis is to analyze the effectiveness of the PPSP utilized at one of the Big Three companies. This work will use the actual practical problem solving (PPS) forms obtained from 6 assembly facilities at the automotive company studied. The forms provided by the company are randomly picked based on the SQDCME issues as stated previously. Each PPS form was separately studied to determine the following:

- Accuracy of information presented in the PPS form completed, in comparison to the standard description.
- The percentage of PPS sheet problems reoccurrence within the same facility and at the different facilities.
- Cost implication or cost avoidance driven by the PPS form.

The study was conducted with the support of the plant management personal, mainly team leaders and supervisors. For the cost determination, the study obtained the cost related numbers from the controller office for each facility. In some cases the study relied on engineering to determine problem root causes when the PPSP reoccurred.

4 Research Limitation

The PPSP process implemented at the Big Three Company in question is part of a lean management culture that the organization has been implementing since 2001. What was obvious during the visit conducted to those facilities is that the organization is still struggling to implement the lean management techniques as a culture due to variables related to issues such

as: union, training, facility constrain, cost constraint, and others. The limitations of the following research are:

- PPSP training survey only included a random sample that included 100 people at each plant (50 management and 50 technicians).
- The study is based only on a random sample of 23 PPS sheets from 6 facilities (based on the facility SQDCME as stated previously), for a total of 138 PPS sheets. The sheets reviewed include problems occurring from May 2010 to September 2011.
- The 6 facilities reviewed are all assembly plants.

5 Research methodology

Documents and surveys were analyzed in order investigate how the Big Three train employees on lean implementation (PPSP technique tool) and the ability of employee to resolve problems. The PPSP process utilized at the Big Three is a seven step process. The steps and descriptions for the PPSP are presented in table 2, the form and or sheet utilized by the big three is presented in Figure 2. In addition, the survey utilized for this study is presented in Appendix A.

The survey conducted included non-skilled employees (technicians) and Management employees. The employees were selected randomly from selected areas based on the PPS sheets given by the plant. For example if the majority of the PPS sheets provided from a specific plant describe problems at the Body Shop (in that facility), the survey was given to that plant to employees in the same zone and department where the problem occurred.

Table 2 The 7 Basic PPSP steps utilized at the Big Three

Step	Description	Details
1	Problem Description	Present a statement (in general terms) describing the current status or situation
2	Problem Definition	Shows a description for the deviation, amount of deviation. Describes the gap between expected and actual results.
3	Short term containment	Provide a temporary solution that prevent the problem from exiting in the department or zone, or contain the problem within a predetermined zone
4	Cause and Effect Analysis	Determine the actual physical location where the problem is first seen Utilize the Fish bone (4 M's), man machine, method and material
5	Identify the root cause	Process through questions and answers that will lead us to the root cause An example is continually asking why ?
6	Determine Long term counter measures	Addresses root cause. Establish the error and mistake proofing to prevent the reoccurrence of the problem
7	Define follow-up mechanisms	After implementing the countermeasures and confirming the implementation, ensure that all the employees are utilizing the countermeasure and that it becomes the new standard process

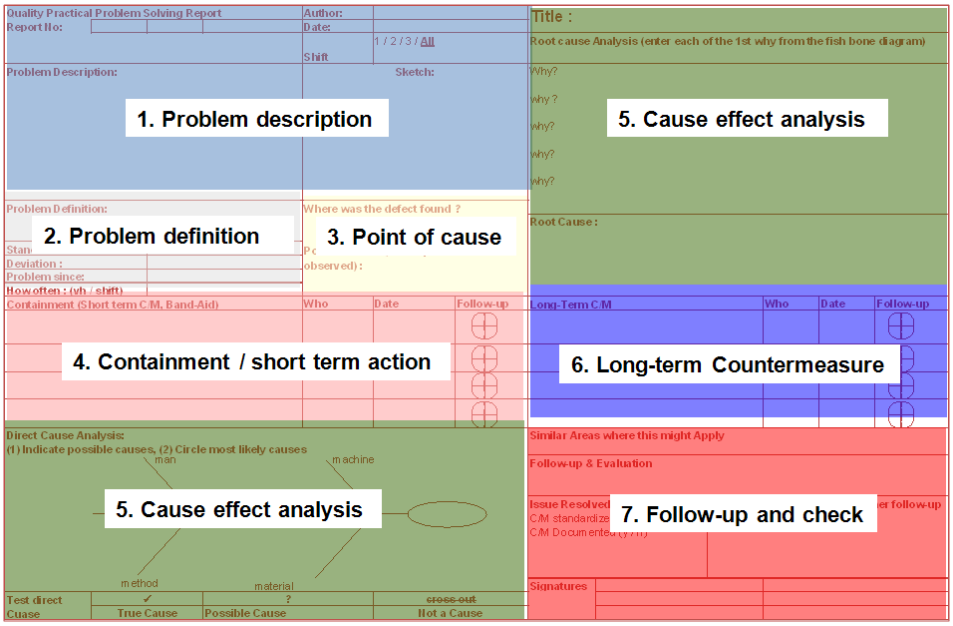
The 138 PPS sheets that are provided by the facility management (randomly chosen) were reviewed with the support of the personnel in charge of the implementation process (typically team leader). Each PPS was given a scale of 1 to 3 for "PPS usefulness" based on the following:

1- The number 1 was assigned to the PPS sheet that is *clear, concise and detailed*. The PPS sheet (with all the steps) clearly explains the problem and the steps taken to resolve it.

2- The number 2 was assigned to the PPS sheet that is *fairly written and can be understood* but requires more details and or support (from facility employee to explain). Part of the PPS sheet is not clear and some of the steps don't detail what, how and when. This sheet needs the problem originator or the team leader support to understand some of the steps followed.

3- The number 3 was assigned to the PPS sheet that is *not clear and difficult to trace*. The PPS sheet is missing information and the reader cannot understand the problem or how it was resolved.

Figure 2 Practical problem solving sheet utilized at the Big Three



PPS sheet were studied for effectiveness based on cost avoidance and problem reoccurrence. The data provided for cost was provided by the facility controller and the problem reoccurrence information was investigated based on production manager input and by physically checking the implementation on the facility shop floor.

4 Results

The following shows the result of the survey conducted:

1- 100% of management and 90% of technicians (non-skilled) employee knew what lean management is,

2- 90% of management and 63.3% of technicians received lean training.

3- From the 270 employees in management that received lean training, 33% took more than two classes in the past 2 years, 67% took only one class in the 2 years. All of the 190 technicians (100%) took only one class in the past year.

4- All management employees (270 employees) trained on lean tools have the knowledge to apply more than 5 techniques and all the 190 technicians (100%) are trained on less than 5 techniques. All technicians are trained on certain lean tools such as 7 waste, 5's, PPSP, and standardized work.

5- Only 15% of the total 300 management employees conducted a PPSP in their zone or department. While only 4% of technicians (mainly team leaders) conducted a PPSP in their zone or department.

6- 75% of management employees indicated that the PPSP is a helpful tool for resolving problems and the other 25% did not believe in the process mainly because their previous experience with the process didn't resolve the problem. On the same issue, the 4% of technicians that used the PPSP believed in the process and the others mainly (96%) indicated that they did not experience the process to make any judgment.

7- The majority of employees surveyed 587 out of 600 (management and technicians) indicated that they trust and believe in the lean process and its ability to improve quality and reduce waste. One technician indicated that "if it works for Toyota and Honda it should work for us". A production manager indicated that "the company can improve its quality but to implement some of the lean tools we have to spend money and for the past 5 years the organization has been cutting without spending on the process or the people".

8- Managers indicated that to improve the PPS process, the upper management needs to show more support and encourage lower managers and technicians. And this support can be translated through providing the resources required for resolving some of the issues and problems faced. As one supervisor indicates "you cannot fix a problem by just

talking about it". Several supervisors explained that their managers prefer to complete the PPS sheet themselves instead of couching them to do it".

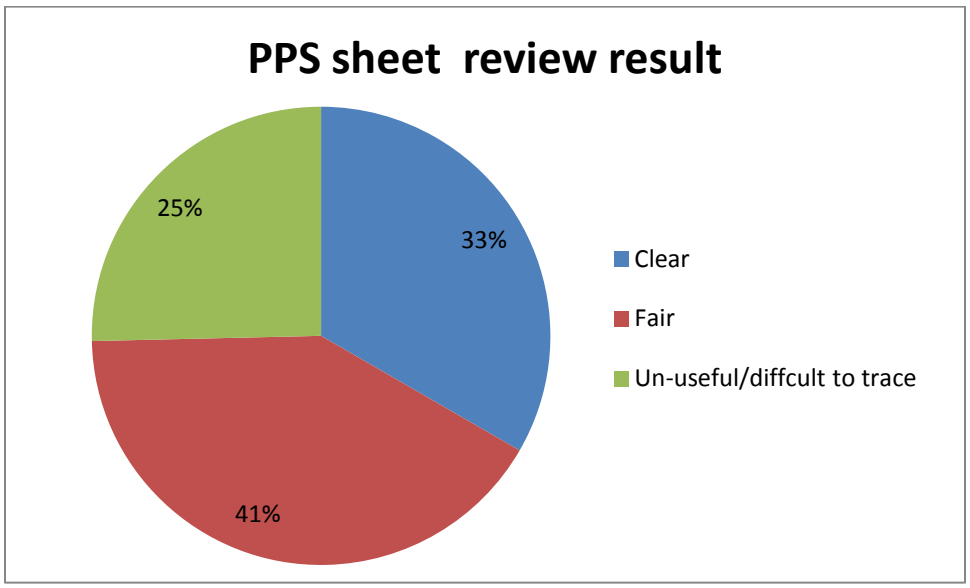
9- Technicians indicated several concerns:

- That management doesn't consider their opinions when it comes to resolving problems at their departments.
- They indicated interest in being part of the problem solving process.
- They indicated their willingness to support other employees in the PPSP if they get training.

Practical problem Solving Sheets result

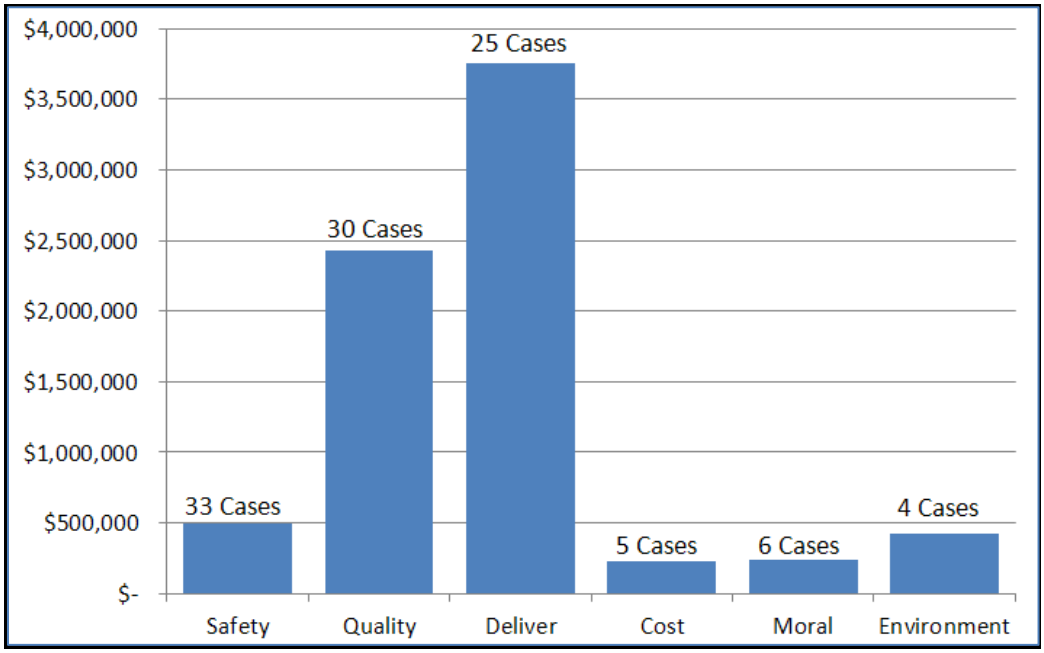
Based on the three rankings described previously, the PPS sheets reviewed showed that while 46 out of 138 sheets (33%) reviewed were clear and could be followed, 35 sheets (25%) were not useful and cannot indicate what was the problem and or the solution identified, as illustrated by Figure 3.

Figure 3 PPS Sheets ranked based on Clear (1), Fair (2), and un-useful (3)



Based on the 103 PPS sheets that were clear and fairly written, the cost avoidance achieved added up to about $7.5 million annually, as illustrated in Figure 4.

Figure 4 Annual Cost Avoidance based on the PPS sheets reviewed by case and SQDCME issue



The study of the PPS sheets also indicated the following:

1- 17% out of the 103 problems reoccurred at the same facility. Team leaders associate the reoccurrences with cause and effect analysis not pointing to the actual cause. Team leaders support that conclusion by their ability to resolve those issues and eliminating reoccurrences after reevaluating the cause and effect step and addressing the actual root cause. Other team leaders indicate that in most cases the "PPSP follow up does not occur and the team does not implement a long term solution since the short term is working".

2- The 17% of the PPS sheets are problems that reoccurred at the same facility and involved only line supervisors and technicians in the team. The follow up sections of the PPS sheets did not include any evaluation criteria. Based on reviewing the old and the new

PPS sheets 100% of the reoccurred sheets in the first time indicated the wrong cause. The process failure was driven by step 5 inaccurate causes.

3- The 83% of PPS sheets that were resolved and never reoccurred involved teams that included: technicians, supervisors, team leaders, engineers, and managers. In addition, these sheets were able to resolve issues with higher time efficiency.

4- 68% of the 103 PPS sheets relate to problems caused by man/labor (cause and effect analysis.

5- 15% of the PPS sheets descriptions indicated identical problems reoccurring at 4 different facilities within a 2 month time frame.

6- 91% of the 35 PPS sheets that are un-useful were written on the 3rd shift by supervisors and or team leaders that did not receive any PPSP training or took only one class in the past 2 years.

7- 85% of the un-useful PPS sheets were written by one individual without the involvement of the zone or department team.

5 Conclusion

Based on the survey and the PPS sheets studied, it is clear that the lean process (including the PPSP) present many challenges for the Big Three as organizations. Overall, the employees are willing to adopt and follow the process assuming they get the training and the support required. During the study at the facilities visited, it was evident that in order for the lean tools to succeed, especially the PPSP, the process will require commitment by the manager and technicians (or union). According to one of the managers surveyed "the pressure that the organization place on us to resolve problems faster drives us to implement solutions without doing our due-diligence to

really understand the root cause". The surveyed employees (management and technicians) understand the challenges facing the organization and they firmly believe in the benefits that the processes like the PPSP can provide, but their main concerns for the success can be summarized in the following points:

1- The managers and or subordinates at all levels need to be involved in the lean initiative specially PPSP,
2- Management need to provide training on lean tools at all levels for all employees and more frequently, managers should take lead in teaching and monitoring progress,
3- The company presented most should create a common PPSP database that can be accessed by all plants therefore, allowing managers and team leaders to be proactive in resolving problems before they occur. This was also evident when reviewing the PPS sheets where similar problems occurred at several plants at separate times. If such a system was in place some of those problems could have been avoided,
4- Employees must be encouraged to get involved and to voice their opinions regarding problems solution in their areas and department.
5- Managers need to dedicate the time and resources in coaching employees including subordinates on conducting a PPSP.

The benefit driven by the PPSP is undeniable; the study shows that a sample of PPS sheets can provide significant improvement (7.5 Million annually based only on 103 PPS sheets). If utilized properly with a team that is efficient (trained) in applying the process, the PPSP is very effective in resolving problems.

In order for the Big Three to compete effectively and efficiently with companies such as Toyota, the problem solving process and or the lean management system requires the support

of the entire organization. The employees at all levels must be involved in training and applying the lean techniques consistently and effectively.

Future work at the Big three in this area should focus on PPSP and lean: training frequency that should be given and training methods applied, level of involvement required by each employee, automation of the PPSP (one PPSP data source), and developing a process to improve managers and employees communication on lean tools.

References

Arnheiter, E., J. Maleyeff. 2005. The integration of lean management and six-sigma. *Emerald insight. 17(1) 5-18.*

Bicheno, J. 2008. *The Lean Toolbox for Service System, Production and Inventory Control, System and Industrial Engineering Book*s, PCSIE Books, Buckingham.

Dewey, P. 1910. *How we Think*, Health & Company, Lexington, MA.

EL-Khalil, R. 2009. *Optimization of flexible body shop system*. (Doctoral dissertation). Retrieved from ProQuest Dissertation and Theses (Accession No 3356289)

EL-Khalil, R. 2011. Pour on the efficiency and standardize car production with work study analysis. *Institute of Industrial Engineering Magazine 43(11) 30-35*.

Hayes, J. R. 1981. *The Complete Problem Solver*. The franklin Institute Press, PA.

Heppner, P., T. Witty, W. Dixon. 2004. "Problem solving appraisal and human adjustment: a review of 20 years of research using the problem solving inventory". *The Counseling Psychologist*, 32(3), 344-428.

Koen, B. V. 1985. *Define of the Engineering Method*. ASEE, Washigton, DC.

Liker, K. 2004. *The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer*. McGraw-Hill, New York, NY.

Liker, J., J. Morgan. 2006. The Toyota Way in Service: The case of Lean Production Development. Retrieved from http://astro.temple.edu/~rmudambi/Teaching/BA951/Week_04/Toyota-Sunny-Side-Liker-Morgan.pdf

Liker, J., D. Meier. 2007. *Toyota Talent*, McGraw-Hill, New York, NY.

Mann, D. 2005. *Creating A Lean Culture*, CRC Press, New York, NY.

Marksberry, P., J. Bustle, J. Clevinger. 2010. Problem Solving for managers: a mathematical investigation of Toyota's 8-step process. *Journal of Manufacturing Technology Management 22(7) 837-852*.

Polya, G. 1957. *How to Solve It: A new Aspect of Mathematical Method*. Princeton University Press, New Jersey, Second edition.

Runarsson, T. 2001. *Evolutionary Problem Solving*. (Doctoral dissertation). Retrieved from http://www.cs.cinvestav.mx/~constraint/papers/eps.pdf. (ISBN 9979-9494-1-4).

Sternberg, R. 1986. The Handbook of Human Intelligent. Cambridge University Press, New York, NY.

Wilson, L. 2010. *How to implement Lean Manufacturing.* McGraw Hill, New York, NY.

Womack, J.P., D. T. Jones. 1996. *Lean thinking*. New York, NY: Simon and Scuster.

Womack, J.P., D.T. Jones, D. Roos. 1990. *The Machine that changed the world*. New York, NY: MacMillan Press

Zhang, Q., K. Liang. 2010. Study on the Organizational Structured Problem Solving on Total Quality Management. *International Journal of Business and Management* 5(10) 178-183

Appendix A

Lean Management Survey

Assembly Plant Number#_____

Name:_____ Date:_____

Department: _____ Zone: _____

1. Do you know what lean management is: YES NO
2. Did you receive any training on lean management tools: YES NO

If you answered yes for question 2 go to questions 3 and 4, otherwise skip to 5

3. How much training was given to you on the lean tools: once a year, once in the past two year, more than once in the past two year (indicate how much_____), other_____.

4. How many tools you were trained on in lean : less than five, more than 5, _____

5. Are you trained to do practical problem solving and do you know how to complete a PPS form?

   Yes NO

6. Have you ever been involved in completing a PPS sheet? Yes NO

7. Do you think that the PPS sheet is a helpful tools in fixing a problem:_____?

If not indicate why?

_____

8. What do you think about the lean management techniques:

_____

_____

9. How do you think your company can improve its product quality:

_____