International Journal for Innovation Education and Research

ONLINE ISSN: 2411-2933 PRINT - ISSN: 2411-3123

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Published Date: 12/31/2017 **Page.01-17** **Vol 5 No 12 2017**

DOI: https://doi.org/10.31686/ijier.vol5.iss12.55

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Abstract

This paper focus on a development and implementation of a systematic guided lean and six-sigma approach to solve high rejection rate on part disposal at composite manufacturing for aircraft component industry. The approach is called PaDLeSS which is stand for Part Disposal reduction through Lean and Six Sigma. PaDLeSS is developed from the integration between lean and six sigma tools with a guided by R-DMAIC-S approach and it is focused on the reduction of parts disposal mainly at a composite manufacturing panel for aircraft components. Since a unit price for one composite panel of aircraftcomponent is very high, a systematic approach to improve, control and sustain the process is necessary in order to reduce parts rejection rate in the process, outgoing process and at the customer process. PaDLeSS is devided into two main phases; development phase and implementation phase. In a development phase, a thorough study was carried out from previous works and match with a requirement needed in part disposal reduction at composite manufacturing for an aircraft panel. The related data related to the parts disposal at the manufacturing line was also analyzed to get actual situation for improvement monitoring. Then, in the implementation phase, a few case studies selected at company A (composite panel for aircraft manufacturing company in Malaysia) for verification and validation purposes. In this paper, the development of PaDLeSS will be presented.

Keywords: PaDLeSS approach, aircraft composite panel, lean, six sigma, Kaizen, Cause & Effect diagram

Introduction

The aerospace industries have proven that composite materials (such as fiberglass & carbon-fiber/epoxy) have superior strength-to-weight ratios & excellent fatigue resistance and its ability to be tailored to different properties by various reinforcement configurations, matrix materials & manufacturing processes. Majority of aerospace components manufacturing in Malaysia using hand lay-up technique to process composite panels. The selection of the hand lay-up process is due to its advantage in the ability to fabricate large & complex parts with a quick initial start-up. However, there is a main disadvantage of hand layup process which is a manual process and depends very much on operator skills. Therefore, it is a necessary to introduce lean and six sigma approaches to reduce process variation and production waste due to the manual processes involved in this type of industry.

Manual hand lay-up process in aerospace industry is exposed to high process variation. The skills between operators are very hard to get constant results in the inconsistency of the product quality. Furthermore, the nature of low volume high mix product produced increases the process variation. This process limitation leads to high rejection rate of the finished and semi finished product. A systematic lean and six sigma techniques need to be developed to solve a high disposal cost for semi finished product in aerospace composite manufacturing company. For example, in company A (aircraft composite panel manufacturer), the company need to absorb millions ringgit (MYR) as a part disposal cost in year 2013. Top defect items causing this high disposal cost need to be identified from the Pareto chart and the causes and actions for each defect item to be determined clearly. Besides that, in order to enable the lean and six sigma techniques applied in the company successfully, the awareness among employees is required. The lean and six sigma culture need to be enhanced among the employees in order to solve the top defect items effectively.

Literature reviews

Lean six sigma is an organizational philosophy of applying relentless efforts to drive waste out of the organization and improve product quality. It is a continuous analysis of the organization to determine where improvement is needed followed by kaizen events and projects. The projects are managed by means of the six sigma define, measure, analyze, improve and control (DMAIC) process using many great tools included in the six sigma knowledge. Lean six sigma is about applying a strategy to improve the business. It can be applied to improve certain areas of business or operations on a tactical level or to achieve strategic objectives. All lean six sigma projects should be driven by metrics. Each area the company desires to improve must be measured to develop meaningful metrics which are most effectively applied via dashboards [1]. A dashboard is a cluster of charts, graphs and other data revealing performance to key metrics. Dashboards are simple, yet powerful tools to communicate progress to everyone in the organization. In Japanese word, dashboard is known as *kanban*.

Six sigma is about reducing the variation of a process. Normally process variation is indicated by a standard deviations (σ). The more standard deviations (σ) that fit between the mean of the distribution and the specification limits (as imposed by the customer), the more capable is the process. A six sigma process means that six(6) standard deviations fit on each side of the mean, between the mean and the specification limits. Six Sigma equates in percentage terms to 99.9997% accuracy or to 3.4 defects per million opportunities to make a defect. Figure 1 illustrates how Six Sigma quality is achieved by reducing variations in a process [2].

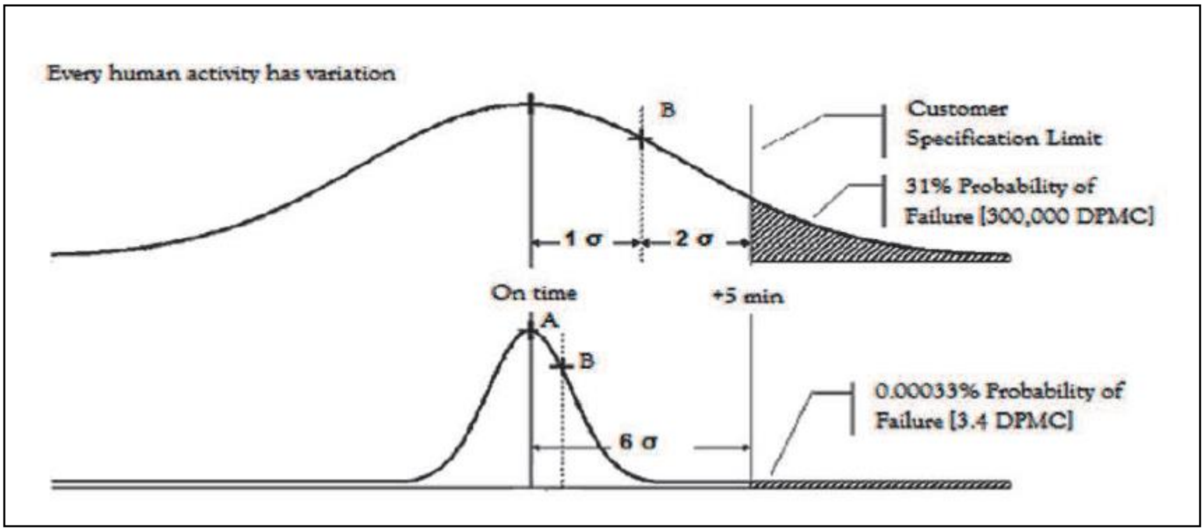

Figure 1 : Reducing process variation using Six Sigma

Six Sigma concepts can be better understood and explained using mathematical term Sigma and Normal Distribution. Sigma is a Greek symbol represented by "□". The bell shape curve shown in Figure 2 is called "normal distribution" in statistical terms. In real life, a lot of frequency distributions follow normal distribution, as in the case of the MP4 Player production pass yield at the SONY production line. Natural variations cause such a distribution or deviation. One of the characteristics of this distribution is that 68% of area (the data points) falls within the area of -1□ and +1□□ on either side of the mean. Similarly, 2□ on either side will cover approximately 95.5% area. 3□ on either side from mean covers almost 99.7% area. A more peaked curve (for instance more and more good MP4 player were made on target) indicates lower variation or more mature and capable process. Whereas a flatter bell curve indicates higher variation or less mature or capable process. To summarize, the Sigma performance levels – one to six sigma are arrived at in the following way.

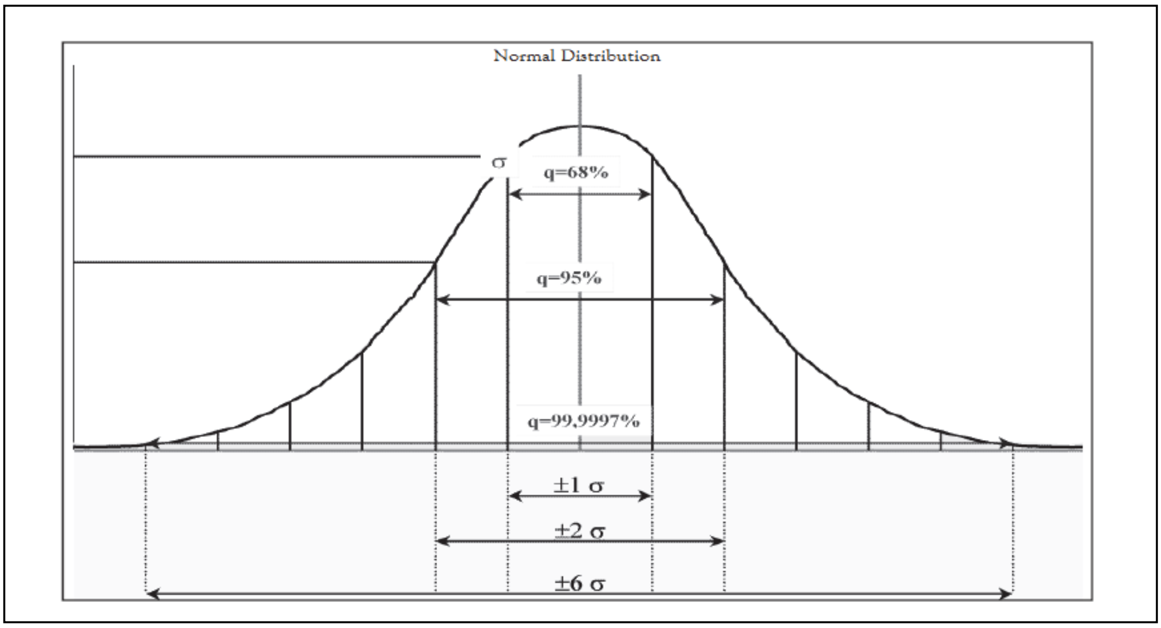

Figure 2 : Normal Distribution

If good MP4 player target is reached 68% of the target output, SONY are operating at +/- 1 Sigma and if 95.5% of the target output achieved, they are operating at +/-2 Sigma. Then, if 99.73 % of the target output achieved, SONY is operating at +/-3 Sigma. 6 Sigma is said to be achieved by SONY if only 3.4 ppm defects is made by the production line, which is equal to 99.9997% of the target output. Sigma Quality Level (SQL) is a measure used to indicate how often the defects are likely to occur. Sigma is a mathematical term and it is the key measure of variability. It emphasizes need to control both the average and variability of a process. Table 1 shows different sigma levels and associated defects per million opportunities. For example, sigma level 1 indicates that it tolerates 690,000 defects per million opportunities with 31% production pass yield. Sigma level 6 allows only 3.4 defects per million opportunities with 99.9997 production pass yield.

Sigma Performance Levels - One to Six Sigma		
Sigma Level	**Defects Per Million Opportunities**	**Percentage Yield**
1	690,000	31
2	308,537	69
3	66,807	93.3
4	6,210	99.38
5	233	99.977
6	3.4	99.99966

Table 1 : Sigma performance Levels

The Six Sigma implementation effects are quantified in tangible savings (as opposed to Total Quality Management (TQM) where the benefits cannot be measured). Quantification of tangible savings is a major selling point for Six Sigma.

Lean manufacturing is another quality and productivity improvement methodology introduced in Toyota Production Systems (TPS) which is based on the concept of elimination of waste in processes which can results in productivity gain and improvement of speed and flow in the value stream [2]. The principle of Lean can be stated as a relentless pursuit of the perfect process through wastage elimination in the value stream. Lean identifies three different kinds of wastes, using Japanese terminology from the Toyota Production System where lean originated:

i) *Muda* (waste of time and materials),
ii) *Mura* (unevenness/ variation), and
iii) *Muri* (the overburdening of workers or systems)

Every employee in a lean manufacturing environment is expected to think critically about his or her job and make suggestions to eliminate waste and to participate in kaizen, a process of continuous improvement involving brainstorming sessions to fix problems. Kaizen is another Japanese terminology which comes from two words “kai” and “zen” which means “change” and “good”, respectively. In a phrase it can be translated as "change for a better" or "improvement". Kaizen is globally practiced in manufacturing companies for production continuous quality improvement (CQI) activities. There are 5 main steps in Kaizen cycles which can be simplified as DAKRS, as shown in Figure 3.

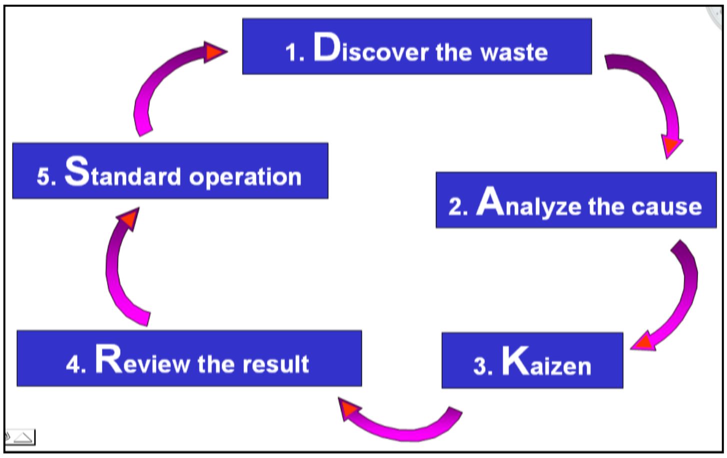

Figure 3 : Kaizen Cycle

The first step in the Kaizen cycle is discovering the waste in the manufacturing processes. There are various types of wastes which are 'hiding' behind the production line processes. Bill Carreira [1] said that if an activity generates revenue, it is not waste but if an activity adds cost and generates no revenue, it is considered waste. This simple description of process waste clearly mentioned that waste is any process which is not adds value to the semi finished product. There are seven typical categories of process waste which are :

a) Overproduction
Overproduction waste can happen either producing something before the next step in the process requires it or producing something before a customer is prepared to purchase it. This waste might be happened due to unbalance cycle time for each operator in the production line and a long setup and changeover times.

b) Excess inventory
Excess inventory is referred to the actual material that is not yet needed that causing cost of people, machines and space besides cost of actual materials and the associated carrying cost.

c) Transportation
Transportation or transport waste is a symptom of layout and linkage between processes. Moving activity of an item from one location to another adds no value. Devices and systems for material transport are also incure huge cost. It is important to design a factory layout with minimum transport of material and semi finished product.

d) Process
Process flow design by production engineer is very critical to avoid any process waste. The process should be focused on value added activities and need to optimize the inspection items with priority given on the customer requirement items.

e) Reject and rework

Variation in the process and the effects of characteristics of material will cause specification differences at each point in the system. A reject can occur at any, or all, steps in this process such as materials and components rejected during incoming inspection, product rejected at any point of internal process, product rejected at final inspection, product rejected after received by customer or product rejected by the end user, returned to customer with a cost incurred back to the manufacturer. Therefore, lean manufacturing need to answer the questions, “How do we design our process so that the variation falls under a Six Sigma distribution curve?” or “How do we create an environment that uses Six Sigma tools and teams to minimize variation and reduce rejects?”. For this research, the reject and rework wastes are the main focus and the KPI (key performance index) is set as a final research objective.

f) Waiting time

There are many causes of waiting time waste such as waiting for materials, inspectors, instructions and equipments. Normally it is due to lack of process definition and unbalance process design. This type of waste might be happen by people, machines, materials and information. Lean manufacturing need to look into improving the linkage between processes so that the balance between people, machines, materials and information could be achieved.

g) Unnecessary motion

This waste is related to people and layout. It is a measure of travel and handling of materials, tools and machines by operator in the layout and process sequence designed. MODAPTS is one of the methods of work study which could be applied during process design in order to avoid motion waste. The ergonomic factor also need to be considered during design the layout to reduce operator’s or user’s fatigues and ease the process.

All items above are nonvalue added activities to the product and not contribute to a more complete product or service and the customer is unwilling to pay for these activities.

Lean Six Sigma approach is how to integrate between lean manufacturing and six sigma approach to improve the company’s profit In terms of either production line pass yield, productivity, on line defect rate or parts disposal reduction (internal and customer return). For this study, parts disposal reduction will be the main focus. The fusion of Lean and Six Sigma is required because lean alone cannot bring process under statistical control and Six Sigma alone cannot dramatically improve process speed or reduce invested capital. Lean Six Sigma is a disciplined methodology which is rigorous, data driven, result-oriented approach to process improvement. It combines two industry recognized methodologies evolved at multinational companies such as Motorola, GE, Toyata, and Xerox. By integrating tools and processes of Lean and Six Sigma, a powerful engine for improving quality, efficiency, and speed in every aspect of business are created[2].

Embedding a rigorous methodology likes lean six sigma into organizational culture is not a short journey, but it is a deep commitment not only to near-term results but also a long term, continuous, even break-through results. Everton and Sergio [3] carried out a good comparison between previous researchers methodology for Lean and Six Sigma tools. There are basically common tools between Six Sigma and Lean, as shown in Figure 4 .

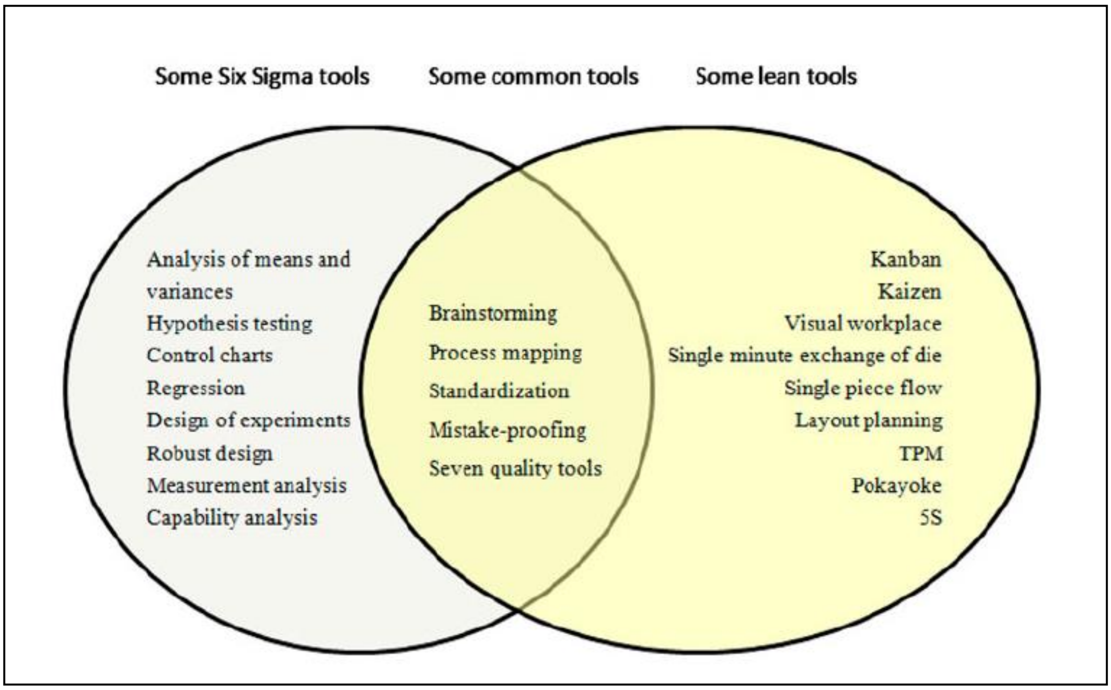

Figure 4 : Six Sigma and Lean tools

The common tools include brainstorming, process mapping, standardization and mistake-proofing. He modified Forza's proposed methodological with six phases and came out with the conceptual model of Lean Six Sigma theory as in Figure 5. He broke down the steps into three simple steps; Initial, Intermediate and Final steps. Initial step involved literature review involving four specific areas of knowledge; operation strategy, lean manufacturing, Six Sigma and Lean Six Sigma. Questionnaires and exploratory survey was carried up in Intermediate step and at the final step, the survey results is analyzed statistically.

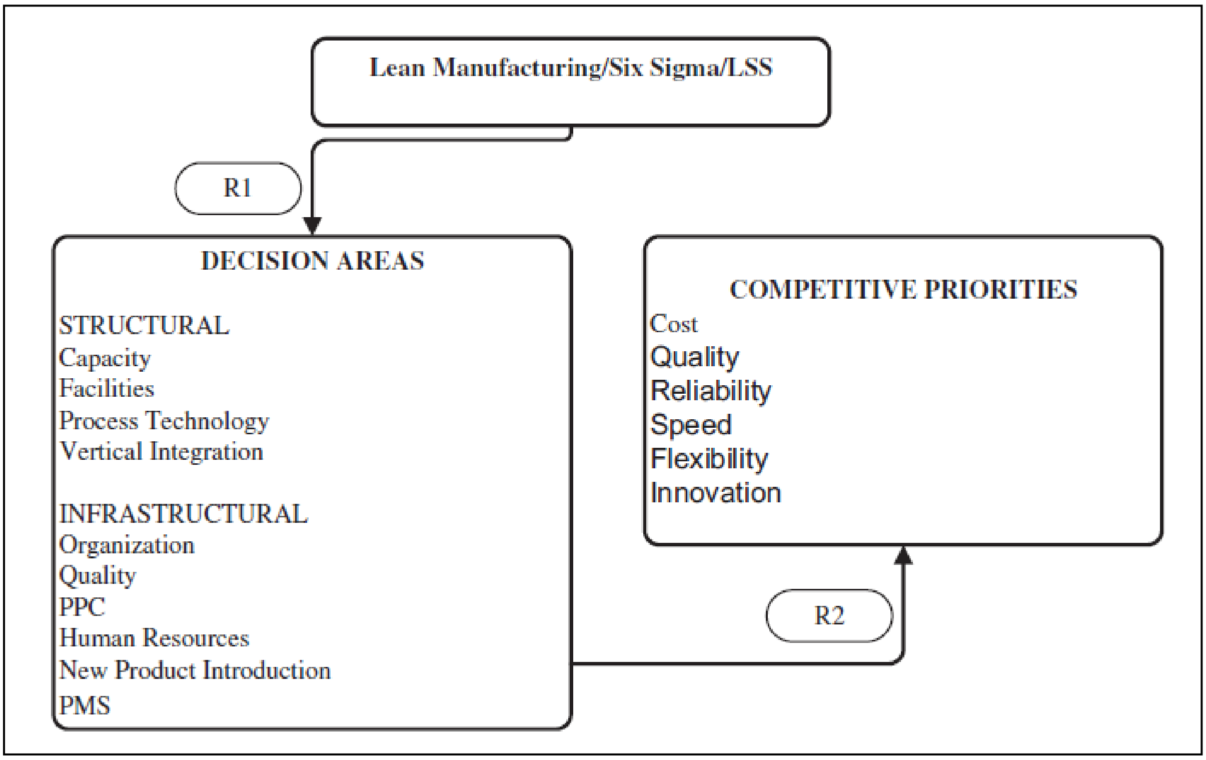

Figure 5 : Conceptual model of Lean Six Sigma theory

Double LEAN Six Sigma approach was developed by Mark and Jagadeesh [4]. Double LEAN means "LL-EE-AA-NN" which consists of four phases; LL (Look and Locate), EE (Explore and Establish), AA (Analyze and Apply) and NN (New and Navigate). First phase LL "Look" at the organization, its customers and processes and "Locate" the process need to be improved. At second phase EE, the company need to "Explore" the process to understand it and "Establish" a baseline after collecting the relevant data. Next in third phase AA, to "Analyze" the problems (or processes), it is necessary to identify the process parameters, steps and link the causes to its effects. Then "Apply" that knowledge to identify the improvement steps by using ANOVA and hypothesis testing. The final phase is NN which means a "New" process is developed based on the evaluation and implementation of the improvements. Plans are introduced to "Navigate" the use of the new process in order to ensure the improvements achieved are monitored and maintained.

There was one study found related to lean manufacturing implementation at Spanish aeronautics industry. The study carried out by B. Prida and M.Grijalvo [5]. Only lean techniques applied in the company in order to reduce process waste (MUDA) but Six Sigma was not integrated together. In this study, the entire assembly line is gathered in a VSM model (Value Stream Mapping) with a combination of a new developed standard which is called VSM-II model. VSM-II model was able to create a snap shot of the system to provide a more precise definition of how the system works. Then, the deviation from standard was measured by using the TMD (Total Mean Deviation) and AMD (Absolute Mean Deviation) equations as performance indicators. The study concluded that the policy of flexibility which allowed for a greater use of manpower, constitute a major barrier to the implementation of lean manufacturing in the company.

The comparison between traditional versus lean manufacturing approach in term of this flexibility is shown in Figure 6.

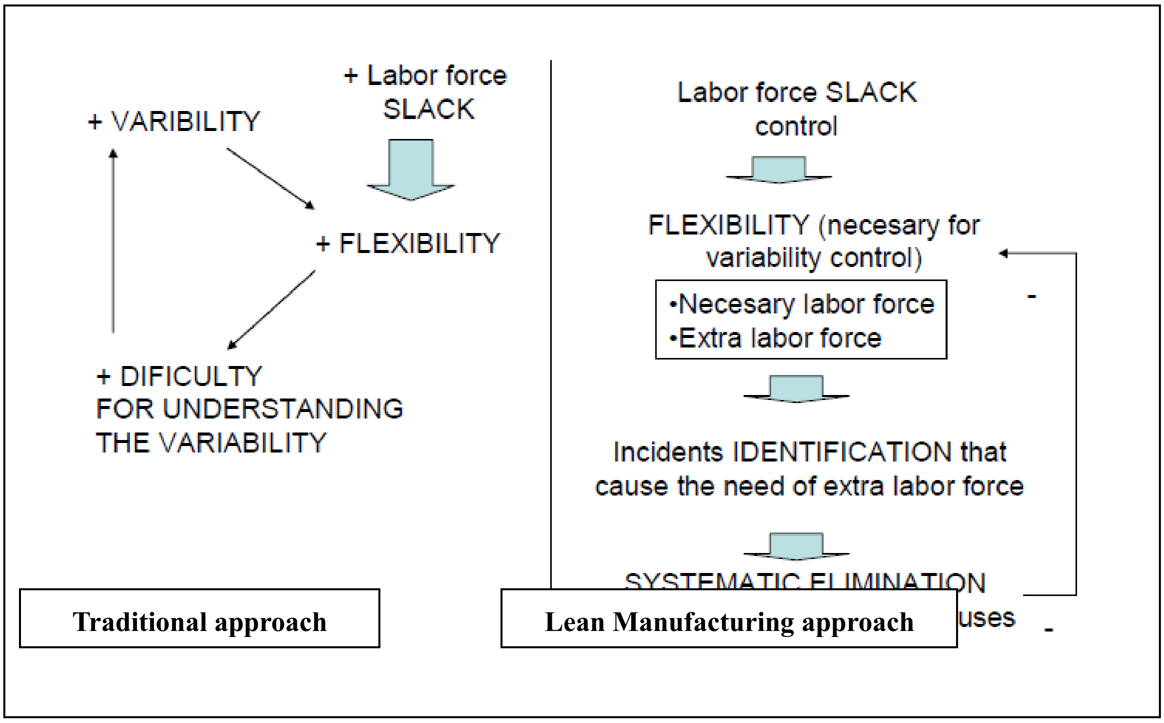

Figure 6 : Traditional approach vs lean manufacturing approach

The study also concluded that when it comes to lean manufacturing, participation from the bottom of the shop floor is vital to the successful implementation of this process. Nevertheless, shop floor participation usually does not occur in companies spontaneously. Training is useful but is clearly not enough. It is necessary to change procedures, practices and policies in order to change the culture of organizations and these changes are not easy to be implemented quickly [6].

The use of composite materials such as carbon fiber reinforced plastics (CFRPs) is increasing especially in structural parts in aircraft industry. Manufacturability needs to be considered in aircraft design to ensure a cost-effective manufacturing process. Frida and Astrid [7] describe the development of a new strategy for how SAAB Aerostructures addressing manufacturability issues during the development of airframe composite structures. Nowadays, the design and manufacturing of parts and subsystems are often outsourced to several different sub-suppliers. The suppliers put strong requirements on cost and time of delivery. According to Airbus and Boeing, the amount of air travel is expected to increase by around 5% in the coming twenty years. This means a higher demand for aircrafts among the world's aircraft manufacturers. DFM (design for manufacturing) is one of the method in Six Sigma could be applied by the companies to meet this demand. One way that aircraft manufacturers are dealing with a demand to lower fuel consumption and environment impact is to reduce the weight of the aircraft by using new types of materials, especially CFRP.

Besides, recently there are many accidents involving aircraft occurs. This makes the giant manufacturer of aircraft (Boeing and Airbus) started to tighten the incoming specifications for the sub-assembly components from the suppliers. Thus besides the technical point of view, a better process control is required to be implemented at the suppliers' production line in order to guarantee the quality of the aircraft components produced. Furthermore, in order to improve profit at the supplier company, inline defects need to be avoided or reduced and continuous quality improvement (CQI) activities need to be absorbed as a company culture. This is where the integration between lean manufacturing and six sigma required.

Alastair [1] proposed a problem solving concept known as R-DMAIC-S cycle. The cycle starts with Recognize (R) where the systematic problems or significant gaps in the business need to be identified. Then, in Define (D) step the business problem need to be formulated and the scope need to be defined. Next, the correct data is gathered in Measure (M) step and the critical to quality (CTQ) to be selected. The data gathered then need to be changed into a stastical problem in Analyze (A) step. At this step, process capability need to be established and performance objective need to be defined. Step 'I' is referred to Improve and at this step the team need to develop a practical solutions. The best improvement strategies must be chosen. Next, in Control (C) step will implement the practical solution where the measurement system to be validated and process control and risk management have to be in place. Finally, in Sustain (S) step the evaluation and report for the Six Sigma project need to be executed.

In this research, both lean manufacturing approaches and six-sigma tools will be integrated together which expected to results in the excellence efficiency and productivity of the production line. The R-DMAIC-S cycle will be used as a guideline for the methodology of the research. Evaluation of this integration will be carried out at one of the aerospace component manufacturer, company A located at northern region of Malaysia to justify the actual result. This company manufactures flat and contoured primary structure (aileron skins, spoilers and spars) and secondary structure (flat panels, leading edges, trailing edges and so on) of composite bond assemblies and sub-assemblies for aerospace industries. One of the major issues facing by the company is high parts disposal cost. A collaboration to be made between researcher and the company's lean and six-sigma team to bring down this part disposal cost. During doing the analysis, all the related lean approaches and six-sigma tools to be utilized.

Even though many researchers had come out with Lean and Six Sigma approaches, there is still a loop hole for validation of this concept at an actual production line especially at aircraft component manufacturing area. Therefore this research will focus on an actual aircraft components production at company A which currently newly set up a lean department to look into the lean and six sigma approaches seriously. At early year 2015, this company is running the production at 2 Sigma level only and generally the lean manufacturing awareness among the employees is still low. The lean department team opinion said that it is very difficult to get cooperation from all the employees in the factory due to low awareness of a lean six sigma among them and need to be improved drastically. Therefore the kick off of this project research is at a perfect time in order to assist the company achieving the key performance index (KPI) set by the company's top management regards the part disposal cost reduction. The tangible KPI which is 50% reduction of the part disposal by end of year 2015 and further 50% reduction by end of year 2016, makes this project very important to the company A's lean department team.

Methodology and approach

By referring to the situation above, a guided Lean-6s (lean six sigma) technique is required to be applied in aerospace composite panel manufacturing company. By this application, the manual process variation could be reduced statistically and unwanted production waste could be eliminated from the production line in order to give a higher productivity and quality of the product. PaDLeSS (Part Disposal reduction through Lean & Six Sigma) is developed as a guided Lean-6s approach to focus on the parts disposal reduction. Company A production line will be selected as a pioneer for the implementation of this approach which targeted to give a big impact to the reduction of part disposal cost. There are two key processes for composite panel manufacturing involved; lay up and trimming processes. For an improvement on a Lean-6s culture among the employees in the company, series of trainings to the employees from all positions (includes operators) could be conducted.

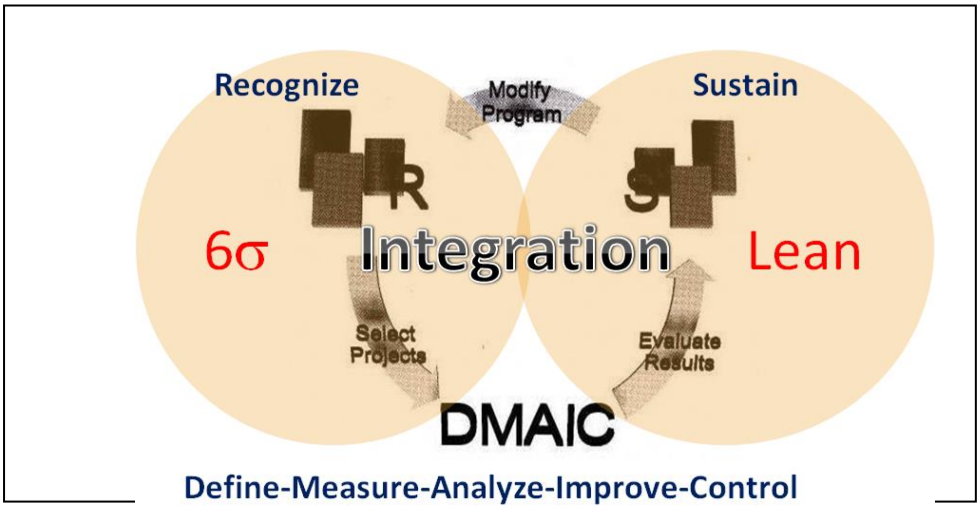

Figure 7: PaDLeSS approach

PaDLeSS approach is shown in Figure 7 where it is a combination of integration between lean six sigma and R-DMAIC-S methods. Its key steps are described in a flow chart, as in Figure 9. The methodology of integration between lean and six sigma approaches is guided by the R-DMAIC-S cycle [8]. The seven steps involved are as follows ; Recognize (R) and Define (D), Measure (M), Analyze (A), Improve (I), Control (C) and Sustain (S)

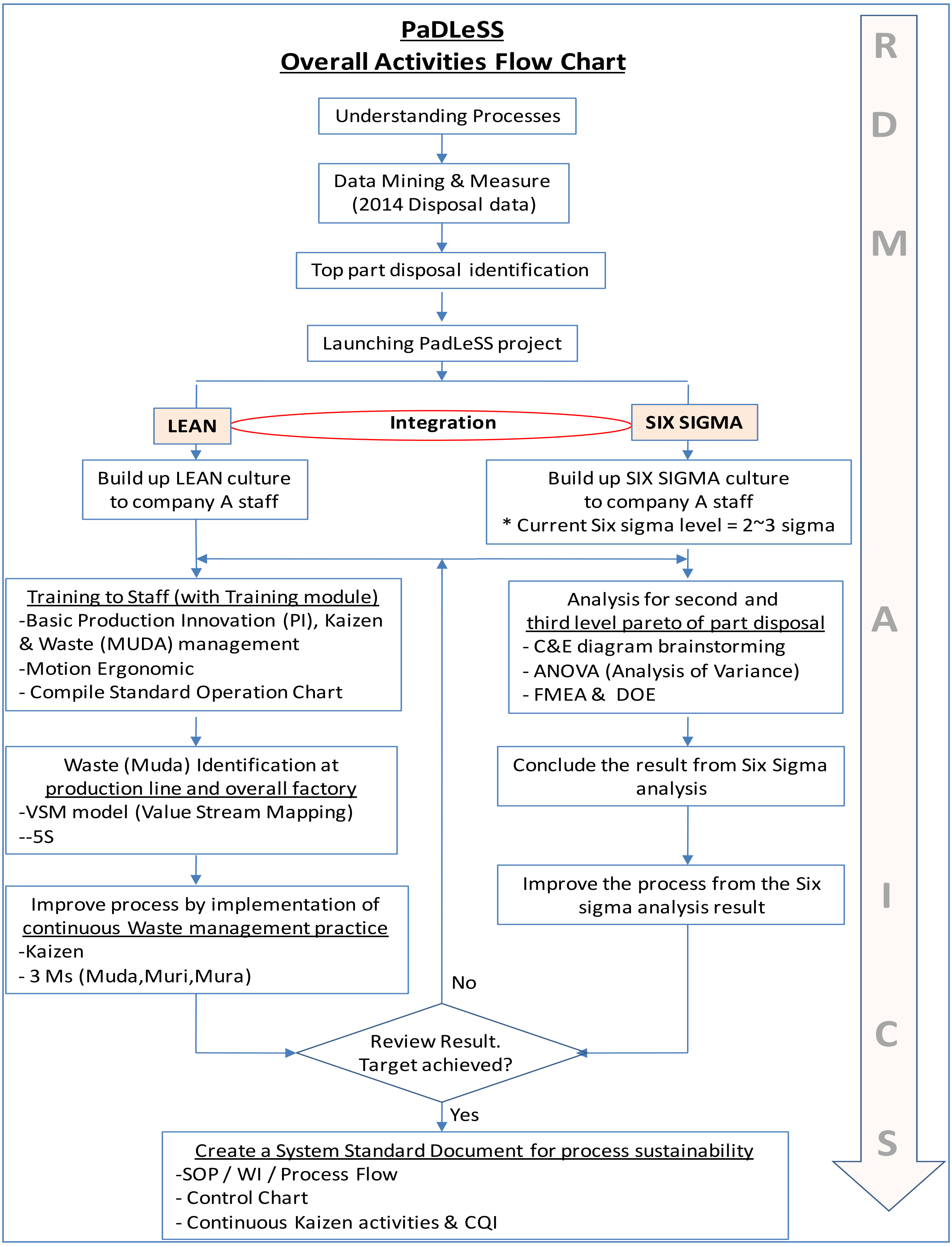

Figure 8: PaDLeSS Methodology

(a) Recognize (R) and Define (D)

The chart begins with recognize (R) step of the problem. One of the major issue rose in year 2014 in company A is very high parts disposal cost. Therefore the parts disposal reduction by half was selected as a key performance index (KPI) to link with the lean and six sigma approaches research. Then in a define step (D), the problem statement, objective and scope of the project need to be clearly identified and written. This work involves the voice of customer (VOC) and the lean six sigma team must listen to this VOC and translate the customer's language into meaningful requirements.

(b) Measure (M)

The next step is measure (M) step with two main purposes ; gather data to validate and quantify the problem (opportunity) and begin teasing out facts and numbers that offer clues about the causes of the problem [9]. In this step, year 2014 part disposal data was gathered and monitored. From the company's parts failure by items data, overall scenario of the pareto for model X disposal parts is shown in Figure 9.

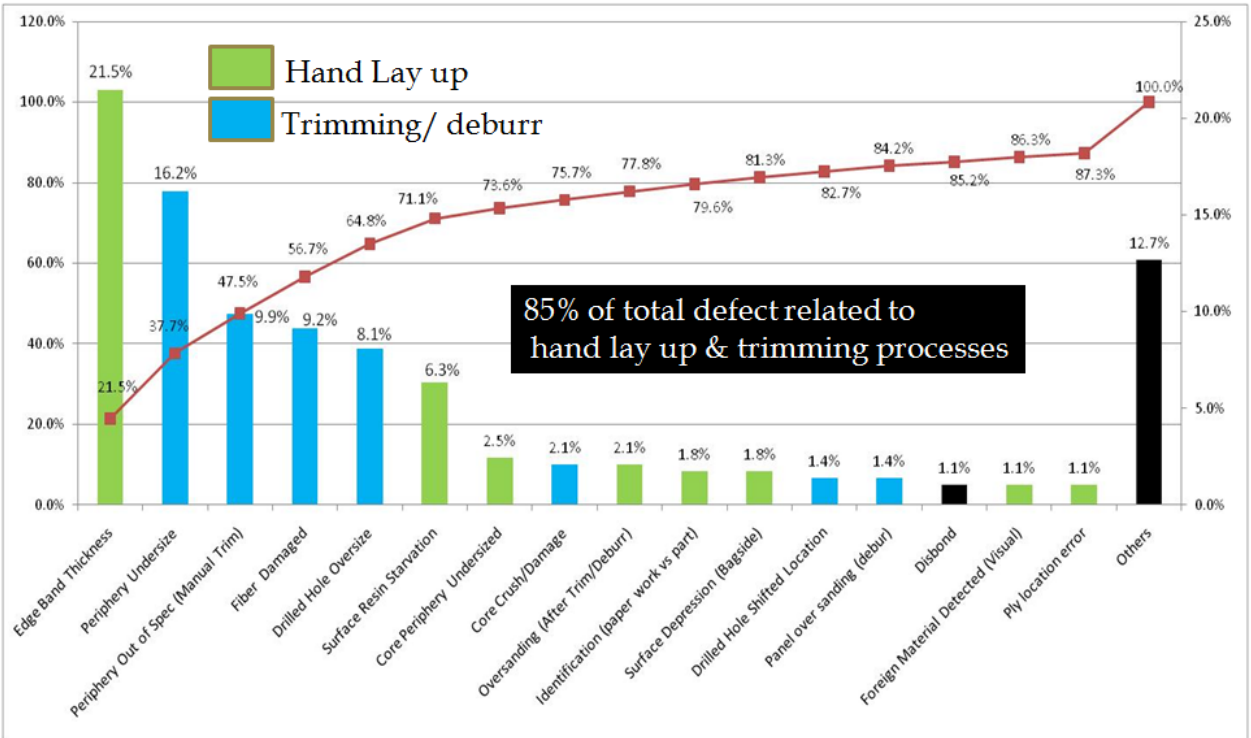

Figure 9: First Level Pareto for model X failure items

From the first level pareto in Figure 9, 85% of the overall defect items quantity are from two main processes ; hand lay up and trimming (deburr). These two processes need to be further studied to get a second level pareto in order to know the root cause of each items. Edge band thickness is a major defect faced by the aircraft company production line which is referred to a thickness dimension of the finished product out of specification when compared to the manual drawings. Periphery out of specification and dimension undersize are other two major defects. Manual trimming process will make the periphery dimension more difficult to be controlled. Fiber damaged also one of the difficult items to be controlled statistically since most of these failures are related to the handling issue.

At the end of M step, the PaDLeSS project was launched and kicked off at company A. From a lean point of view, the lean manufacturing awareness among employees in company A need to be measured. This could be done by giving the survey questions to the employees for them to answer. As for a six sigma point of view, the measurement should be focused on the sigma level which is currently practiced by company A. From the measurement, it was finalized that the awareness of lean manufacturing among employees is still low and the company's production is only running at 2 to 3 sigma level (approximately at 70% to 90% yield). As a result, the researcher feels that the lean six sigma culture at company A is still need to be built up and this action should be put as a priority.

(c) Analyze (A)

In this step, the team will use it to find the root cause of the problem. One of the principles of good R-DMAIC-S problem solving is to consider many types of causes, so that not to let biases or past experience cloud the team's judgment [9]. The most common six sigma tool could be utilized here is Cause and Effect (Fishbone) diagram. Some of the common cause categories to be explored are (6 M's) as follows :

i) Methods : the procedures or techniques used in doing the work

ii) Machines : the technology used in a work process such as manufacturing equipments, computers and copiers

iii) Materials : the data, instructions, numbers or facts, forms, and files that if flawed, will have a negative impact on the output.

iv) Measures : faulty data resulting from measuring a process or changing people's actions on the basis of what's and how it is measured.

v) Mother Nature : environment elements, from weather to economic conditions that might impact on process or business performance

vi) Man : factors caused by human being due to fatigue and it is a key variable to produce business result.

Figure 10 shows the cause and effect diagram for top failure of the part defect which is Edge Band Thickness (EBT) failure.

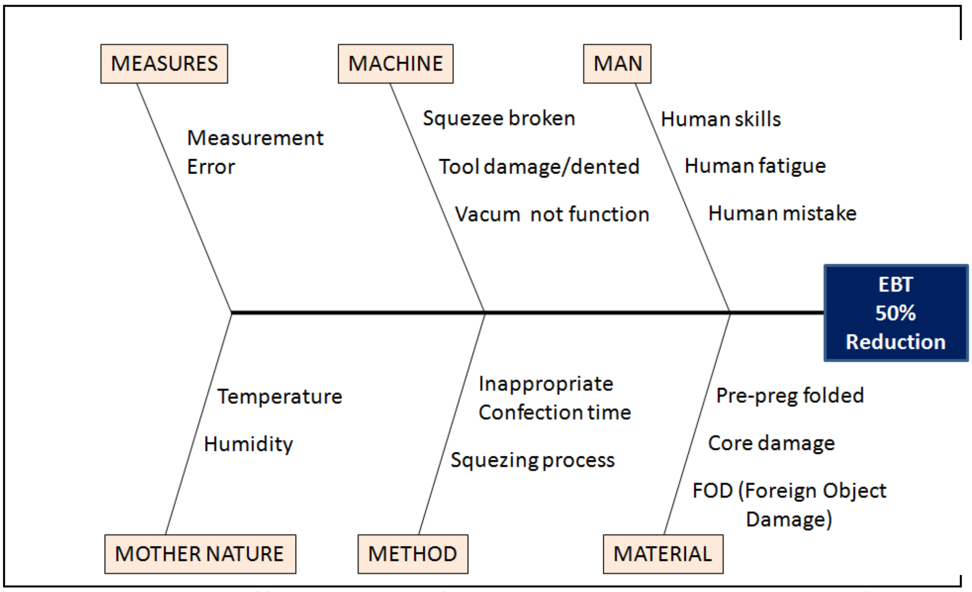

Figure 10 : Cause & Effect Diagram for Edge Band Thickness (EBT) failure item

One of the big challenges in analyze step is to select a right tools. When causes go deeper or when the relationship between the problem and other factors is complex and hidden, more advance statistical techniques may be required to identify and verify the cause. From Figure 8, at the beginning of step A, a training to employees were conducted in order to familiarize them with lean six sigma culture. The training to be conducted includes basic production innovation (PI), kaizen and waste (Muda) management, motion ergonomic and compile standard operation chart. Then for lean, waste at production line and the overall factory need to be identified by using Value Streaming Mapping (VSM) and other related tools. As or six sigma, analysis need to be carried out for a second and third level pareto of finding a root cause for the part disposal issue. This could be achieved by using six sigma tools such as Cause and Effect diagram, Analysis of Variance (ANOVA), Failure Mode Engineering Analysis (FMEA) and Design of Experiment (DOE). The analysis step conclusion is then concluded before move to a next step.

At this analysis step, the knowledge and theory about advance composite materials and its manufacturing processes need to be known and understood well by the researcher and team members. Discussion and brainstorming sessions among team members need to be carried out regularly. All the limitations such as specification by Boeing and Hexcel need to be understood as a scope of the analysis.

(d) Improve (I)

After conclusion has been decided from the analysis step, it is time to start the improvement. A traditional method of improve and solving problem is called 'Fire Fighting' or 'See problem, Kill problem' method. In this method, the repairer or engineer tends to straight away try to look into a temporary solution or countermeasure without finding as actual root cause of the problem. This method also sometimes happens in company A. The disadvantage of this method is although the problem is solved, it may be repeated since the actual root cause is not solved. With systematic tools in a lean six sigma approach, the cause of a problem could be solved until the root of it. From a lean point of view, an improvement could be done on the continuous waste management practice. This includes Kaizen implementation, 5S and 3 M‘s (Muda, Muri, Mura) improvement. As for a six sigma view, production line processes need to be improved according to the statistical and non statistical result obtained from analysis step.

(e) Control (C) and Sustain (S)

Control and sustain step is very important in order to make the improvement carried out in previous step could be remained. Otherwise the problem and the similar cycle of solving might be repeated again and again. Firstly, the improvement items need to be reviewed regularly. In this project the review to be carried out at every two months. If the result found diverting from its lower and upper control limit, action need to be taken immediately. A system standard document for process sustainability needs to be created by the team for easy monitoring. The most common lean six sigma tools to serve this purpose are Standard Operating Procedure (SOP) or Work Instruction (WI), Process Flow, Statistical Process Control Chart (SPC), continuous Kaizen activities and Continuous Quality Improvement (CQI).

Specific control tasks that must be completed by the teams include [9] :

i) Developing a monitoring process to keep track of changes they have set out

ii) Creating a response plan for dealing with problems that may arise

iv) Helping focus management's attention on a few critical measures that give them current information on the outcomes of the project

Conclusion

PaDLeSS as an integration between lean manufacturing and Six Sigma (lean six sigma) with a guideline from seven steps in D-DMAIC-S expected to give a big impact to company A in term of part disposal by end of the research period, hence meeting the KPI set by the top management. Its holistic approaches cover all the important area especially from lean point of view which is waste elimination and six sigma point of view which is process variation improvement. This study concluded the PaDLeSS approach and methodology could be applied by aircraft composite manufacturing in order to reduce the part defects in the production line hence improve the psrtd disposal cost.

References

[1] Bill Carreira, 2006, **Lean Six Sigma That Works**, Amacom, New York

[2] Vivekananthamoorthy N & Sankar S, 2010, **Lean Six Sigma, Six Sigma Projects and Personal Experiences**, ISBN:978-953-307-370-5

[3] Everton D. & Sergio E.G., 2013, **Lean, Six Sigma and Lean Six Sigma: an analysis based on operations strategy**, *International Journal of Production Research*

[4] Mark G. & Jagadeesh R., 2011, **Double LEAN Six Sigma – A Structurefor Applying Lean Six Sigma**, Journal of Applied Business and Economics: vol.12(6)

[5] B.Prida & M.Grijalvo, 2011, **Implementing Lean Manufacturing by Means of Action Research Methodology Case Study in the Aeronautics Industry**, *International Journal of Industrial Engineering, 18(12),611-619*

[6] Goddinho M.,Faria F.C., 2009, **Strategic Paradigms for Manufacturing Management (SPMM): Key Elements and Conceptual Model** , International Journal of Industrial Engineering: Theory, Applications and Practice, 16(2):147-159

[7] Frida A., Astrid H., 2014, **Design for Manufacturing of Composite Structures for Commercial Aircraft – the Development of DFM strategy at SAAB Aerostructures**, *CIRP Conference on Manufacturing System: 17(2014) 362-367*

[8] Alastair K Muir, 2006, **Lean Six Sigma Statistics – Calculating Process Efficiencies in Transactional Projects**, McGraw-Hill, New York

[9] Pete P & Larry H., 2002, **What is Six Sigma**, McGraw-Hill, New York

[10] Susan K.L., Dauglas B.S., 2008, Practical **Support for Lean Six Sigma Software Process Definition**, Wiley, New Jersey

[11] Keki R.B.,2003, **The Power of Ultimate Six Sigma**, Jaico Publishing House, Mumbai

[12] James W.M., 2007, **Lean Six Sigma for Supply Chain Management – The 10 Step Solution Process**, McGraw-Hill, New York

[13] E.A. Parr, 1998, **Industrial Control Handboo**k, 3rd Ed, Industrial Press, Oxford

[14] Jon D.S., 1999, **Evaluation of Hand Lay-Up and Resin Transfer Molding in Composite Wind Turbine Blade Manufacturing**, Montana State University-Bozeman

[15] Adan V & Jaime S., 2009, **Implementation of Six Sigma in a Manufacturing Process: A Case Study**, *International Journal of Industrial Engineering: 16(3),171-181*

[16] M.White & J.L.Garcia, 2009, **Cycle Time Improvement by a Six Sigma Project for the Increase of New Business Accounts**, *International Journal of Industrial Engineering: 16(3),191-205*

[17] Daryl S., 2009, **Beyond Six Sigma – A Control Chart for Tracking Defects per Billion Opportunities(dpbo),** *International Journal of Industrial Engineering: 16(3),227-233*

[18] Jerusha M.& Tracy B., **Professional Perceptions of Six Sigma's Value**, *International Journal of Industrial Engineering: 16(3),234-247*