Reducing the scrap rate in an electronic manufacturing SME through Lean Six Sigma methodology

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ABSTRACT

Purpose – The aim of this project was to reduce the level of scrap rate in the production of a product known as the "Remote Acceleration Sensor (RAS)" that is used for Air Bags through Lean Six Sigma (LSS) methodology.
Design/methodology/approach – This is an action research that was conducted in a single case study and used the LSS methodology of DMAIC concentrating on one fully automated sub-process of the production called the "Overmould line".
Finding – It was found that implementing DMAIC methodology had an effective impact on the production and scrap rate was reduced achieving the 99.03% First Run Yield (FRY) from 98.4% FRY before implementation. This was the improvement from 3.65 to 3.85 in the Sigma scoring term with significant financial impact at this scale.
Research Limitations/Implications – This action research could be deployed in other sub-processes of the production line, other processes of the company and could also be conducted in more than one single case study from the same sector. The research investigation needs to be fully controlled by the team in order to correctly gauge the effect of any changes made to the process.
Practical Implications – This project adds further evidence of effectiveness of the LSS methodology in manufacturing SMEs through adding value to the process and reducing the scrap rate and waste. The project had greater saving than expected by the managers at £98,000 per annum. This saving could even be higher when the company is expanded.
Originality/Value- The approach of this research project combines proven statistical tools with some basic but effective lean tools to be applied in an original sequence in order to design robust product and match manufacturing capabilities.
Key Words – Lean Six Sigma, Six Sigma, DMAIC, Manufacturing, SMEs, Scrap Rate

1. Introduction

Process improvement and operational cost reduction through quality improvement practices has been at the centre of attention for many businesses in different sizes and in a variety of sectors to gain a more competitive advantage. Lean Six Sigma (LSS) is an effective and disciplined business transformation strategy and problem solving tool that has evolved through the combination of Lean and Six Sigma, both recognised as leading Total Quality Management (TQM) tools for performance improvement in organisations with a proper infrastructure built on leadership and change culture (Dora and Gellynck, 2015; Assarlind et al, 2013; Wang and Chen, 2012; Choi et al, 2012; Hilton and Sohal, 2012; Atmaca and Girenes, 2013; Lee et al, 2011; Delgado et al, 2010). The effective top-down methodology of LSS in both manufacturing and service Small to Medium – Sized Enterprises (SMEs) has been acknowledged by researchers and practitioners (Kanpp, 2015; Isa and Usmen, 2015,

Bhat et al, 2014, Algasem et al, 2014; and Brianvand and Khasseh, 2013). In fact, there have been many research studies available in relation to Six Sigma implementation in manufacturing SMEs with the focus on improving the quality of the product, customer satisfaction and financial enhancement (Albliwi et al, 2015; Brun, 2011; Antony et al, 2005; Antony and Desai, 2009; and Kaushik and Khanduja, 2009). The term SME for the purposes of this study uses the EU definition of any organisation with less than 250 employees (European Commission, 2003 and Department of Trade and Industry DTI, 2005 cited in Kumar et al, 2009).

However, despite of growing number of research studies and case studies in manufacturing SMEs (Dora and Gellynck, 2015; Thomas, 2009; Gijo, 2014; and Cournoyer, 2012), the LSS research and application with the purpose of waste reduction would need further attention by both researchers and SME practitioners. The purpose of this project was to reduce the level of scrap rate in the sub-process of a vision inspection system as part of the fully automated process of "Overmould Line". Although the company is practicing LSS as part of company establishment, this problem has been prioritised at this stage due to being considered as a key measure for waste and cost reduction through LSS methodology. This problem may also be more serious in upcoming years due to expansion plans. This production line is used to produce a product known as the "Remote Acceleration Sensor (RAS)" that is used for air bags. The role of the vision inspection system (Figure 1) in the Overmould Line is to determine whether the dimensions of the pins inserted in the board are to the customers' specifications before the unit is injection moulded.

Figure 1 – Vision Inspection Process

2. LSS in manufacturing SMEs

LSS is an appropriate approach in managing waste and variability to keep the operating expenditures to the minimum (Ismail et al, 2014). It has been emphasised by researchers that focusing on low hanging fruits will have the best and most productive results in any LSS project (Dora and Gellynck, 2015; Choi et al, 2012), which perhaps could even be more

appropriate for the SMEs due to being more restricted in resource availability. Although it has been suggested that LSS could be deployed in SMEs similar to their larger counterparts with consideration of specific resource management (Kaushak et al, 2012), it has also been argued that its application for SMEs could be considered in a different perspective (Kumar et al, 2011; Kaushik et al, 2012). This could be extended to different scales in financial gains.

At an operational level within the manufacturing sector, the LSS model aims to clarify the process of identifying opportunities for non-value added activities, as well as reduce variability and improve the process cycle time and quality of the manufacturing process (Bamford et al, 2015; Holmes et al, 2015; Worley and Doolen, 2015; Sarkar et al, 2013; and Thomas et al, 2009). This will result in some strategic benefits such as customer satisfaction, financial enhancement and more efficiency in manufacturing processes (Shafer and Moeller, 2012; Cournoyer et al, 2012; Jayaraman et al, 2012; Gupta et al, 2012; and Manville, 2012). Despite all of these benefits, "internal resistance", "the availability of resources", "changing business focus", and "lack of leadership" have been suggested as the greatest impediments to implement LSS in any manufacturing SME (Timans et al, 2012).

Scrap rate is one of the common elements of the cost of poor quality, which may appear as the result of high defect and variability level in any manufacturing process. Scrap rate could potentially have negative impact on increasing the process cycle time and therefore generating extra cost and uncertainty to supply the products (Hilmola and Gupat, 2015). It was evident from recent research studies that scrap rate could be significantly reduced through LSS deployment in the automotive sector (Orbak, 2012). By utilising the LSS five-phased systematic methodology of DMAIC (Define, Measure, Analysis, Improve, Control) manufacturing SMEs can tackle any process variation and defect including scrap level (Prashar, 2014; Gupta et al, 2012; and Orbak, 2012). The next section presents the case study and methodology of this research project.

3. Case Study and Research Methodology

The client is a 1st tier automotive supplier who specialises in sensor and safety electronics and has already been implementing some LSS projects. The company has hired one Black Belt (BB) with few Green Belts (GB) and this project has been conducted by a GB with the supervision of the BB. The managing director of the company has the power of approval and project tollgate review as the Champion. The approach taken to complete the scrap reduction of the Overmould line was that of inductive case study and action research. Action Research is viewed as a research strategy in which the researcher is working collaboratively with practitioners and directly involved in the organisational change (Suanders et al, 2012; and Avisonet al, 2001). Researchers believe this could be the best possible research methodology for this study, since a production failure as a contemporary phenomenon will be investigated in a real life context. The data collection and data analysis methods of this study are in accordance with the LSS methodology of DMAIC. The next section presents the phases of this methodology that has been applied as part of a LSS project.

4. Results

Define

Scrap reduction has been part of the corporate standard for quality for the client. The Overmould line scrap, which contributed to 18% of the total scrap level in the factory corresponding the cost of £130Kwithin the course of three months investigation, has been

nominated as a priority for the next LSS project. In order to reduce the scrap produced by the Overmould line a cross functional team was assembled, which included a quality engineer (Green Belt), a manufacturing engineer, production staff, a Black Belt and a senior manager who acted as the sponsor of the project. The project goal was established to reduce the level of scrap produced on the Overmould line from the current value of 3.52% of its own product sales down to 1.5% representing the FRY improvement from 98.4% to 99%. A closer look at the data for the Overmould line identified four main sub-processes contributing to the level of scrap (figure 2). The problem of the 1st stage Overmould process and its solution were already known by the process engineer and steps had been taken to resolve this. Therefore the second problem sub process was taken on which was the vision inspection system. The vision inspection system ensures that the part is compliant to the customer's specification by measuring seven different characteristics of the Printed Circuit Board (PCB) at that point in time. The tools used to fully outline the project to be completed were: a SIPOC diagram, High Level Process Map (Appendix A), CTQ tree, and a Project Charter (Appendix B).

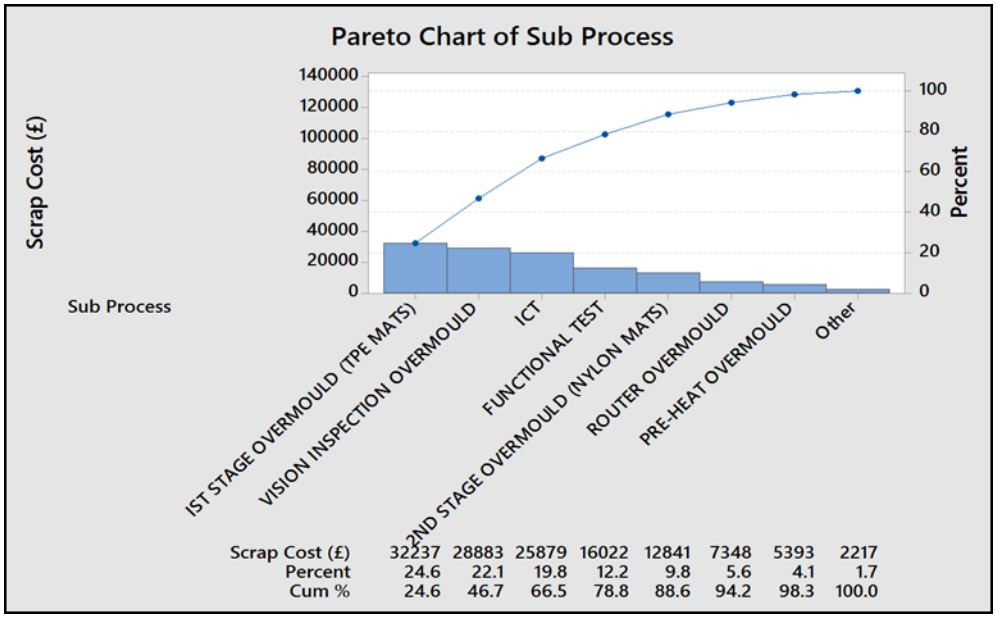


Figure 2 - Overmould Sub Processes Scrap cost Pareto Chart

Measure

The system's ability to be measured has been approved through Measurement System Analysis (MSA). The baseline performance of the line was determined through the FRY data collected over the three months prior to the start of the project. The control chart in Figure 3 represents the average 98.4% FRY resulting in a sigma score of 3.65. The vision inspection system uses seven different parameters to determine whether the part is within specifications. When generating the process capability for the system, each of the seven parameters was treated individually with the results displayed in Table 1. The Normal Distribution for Parameter 2 has been provided in Appendix C as the sample.

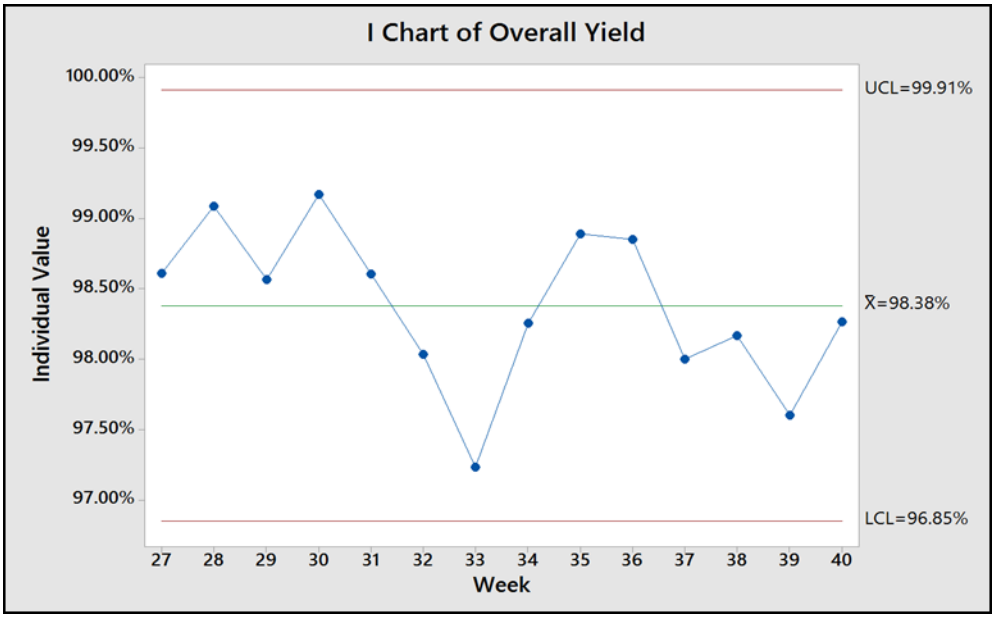


Figure 3 – Baseline Performance Control Chart

Parameter	Specification	Process Capability/Cpk
1- Long to short pin (Vertical)	4mm ± 0.5mm	1.62
2- Bottom of PCB to long pin	11.1mm ± 0.5mm	0.8
3- Left right offset long	0mm ± 0.6mm	0.88
4- Left right offset short	0mm ± 0.6mm	1.63
5- Horizontal distance between pins	0mm ± 0.6mm	2.08
6- angle between PCB border and pin	90 degrees ± 3 degrees	1.66
7- long to short pin (Horizontal)	0mm ± 0.8mm	0.32

Table 1 – Process Capability (Cpk) for all 7 parameters

Analysis

To start off the analyse stage, a brainstorming session was held in order to identify the potential issues with Vision Inspection. The personnel involved with the brainstorming session were the Six Sigma team and the line operators. The results of the brainstorming session were displayed as a Cause and Effects Analysis diagram (Figure 4). The validity of these ideas was determined by the analysis of the data identified in the data collection plan. The review of process capability analysis revealed that parameters 2, 3 and 7 have Cpk of 0.8, 0.88 and 0.32 respectively. These values are much less than those expected for a capable line, which would be in the region of 1.33 by the Company's standard.

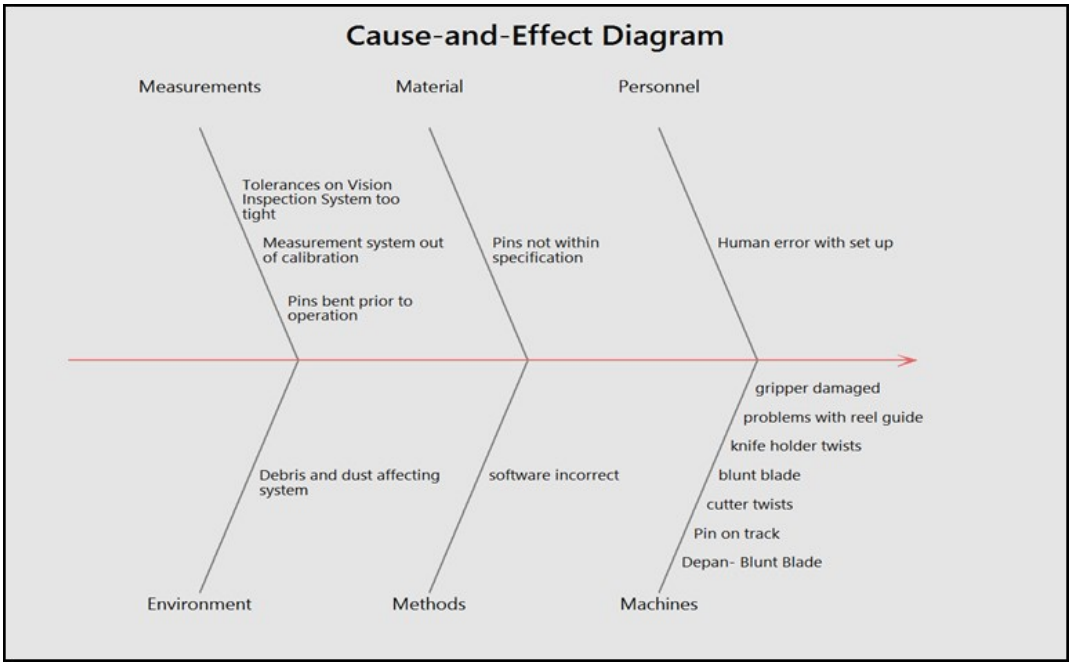


Figure 4 – cause and Effect Diagram

A Gemba investigation has been set up in the production line and the first problem that has been identified was related to the cleanness of the Vision Inspection system. A Gemba or Gemba Kaizen is a method which is meant to be a technique of line inspection in which obvious problems are able to be rectified in a short period of time (Tyagi et al, 2015; and Burton, 2011). The brighter parts identified by the circle in pictures taken by the camera (figure 5) show debris on the nest which can lead to an incorrect measurement of the thickness of the pins as the system will take the debris as the datum point rather than the edge of the pin. It was revealed that debris have been coming from previous process (Depanelisation).

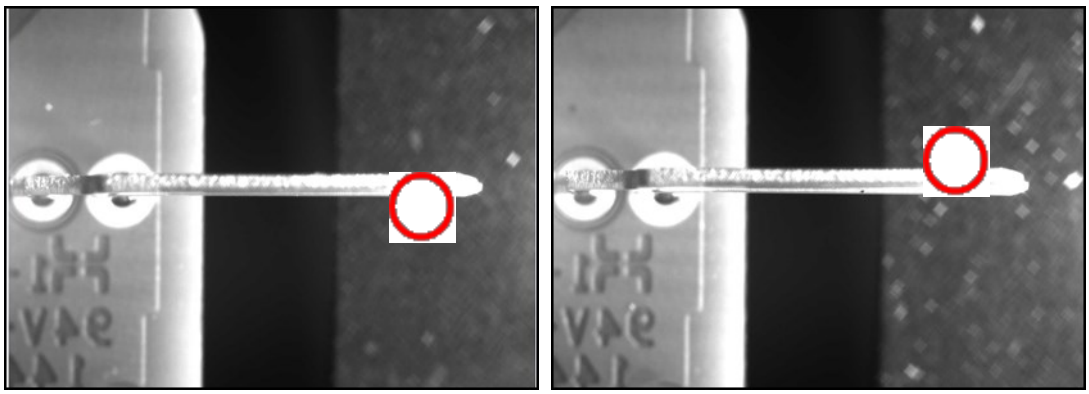


Figure 5 – camera view of the debris on the nest

The second problem was identified as the variation in programme set for the vision inspection system for different customers, despite of measurement against the same specification. This will result in slight shift of the measurement and also changeover time between different

customer parts. The final note that has been taken as the result of Gemba investigation was related to the tight clamp on the first moulding cell, which will tighten the tolerance compared to customer specification (figure 6).

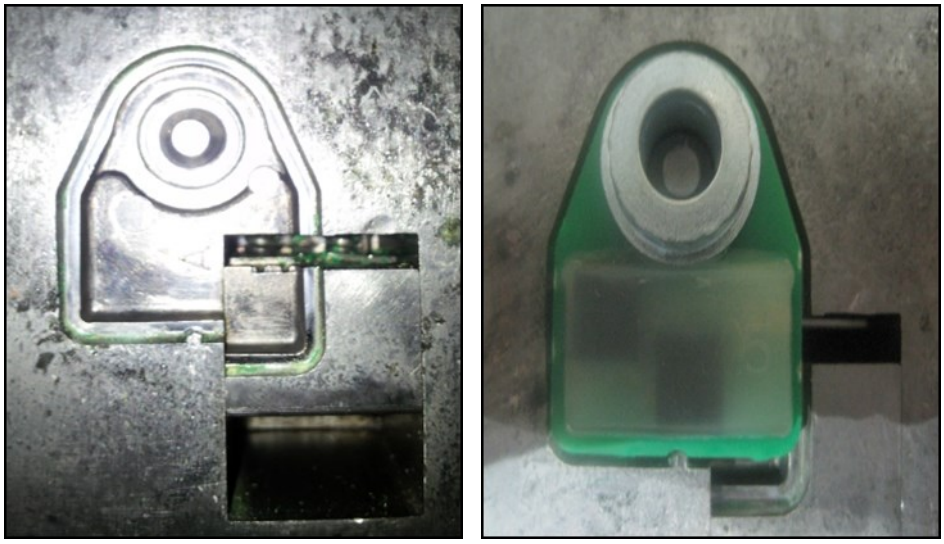


Figure 6 – First Moulding Pin Clamping Mechanism

The dimensional testing of 30 scraped parts as samples against the engineering drawing by the use of a Co-ordinate Measuring Machine (CMM) confirmed that all parts were genuinely failed.

Improve

The Analysis phase uncovered three issues as dust and debris on the PCB nests, the too tight tolerances and multiple Vision Inspection programmes. In order to generate a set of solutions for these problems a brainstorming session was conducted. The solution for debris on the nest has been agreed as having regular cleaning procedure for Depanelisation process in 8 hours intervals and also treating the Vision Inspection cell with Ioniser regularly to reduce the static electricity and remove the debris on the nest. An experiment was conducted with two different sets of tolerances as two trials setting applied to the Vison Inspection process of the 1st stage Overmould and Pin check (Table 2). The first of tolerances include an increase in the three parameters shown to be below the expected level of process capability while the second also increased the parameter relating to the angle of the pin in relation to the PCB. The DoE was not feasible at this stage due to time constraints limited to 4 hours to complete the trail to prevent any interfere and also nature of improvement strategies that would have minimum interactions with each other.

The results of the experiment revealed that both trails setting improve the process capabilities of the parameters examined with no failures at either the 1st stage Overmould or at Pin check (Table 3). To re-iterate the result the Normal Distribution for Parameter 2 after the improvement has been provided in Appendix D, where the difference in productivity and process performance compared to before the improvement is evident.

Parameter Set	Parameter 2	Parameter 3	Parameter 6	Parameter 7
Standard Settings	11mm ± 0.5	0 mm ± 0.6	90° ± 3	0 + 0.8
Trial 1	11 mm ± 0.7	0 mm ± 0.8	90° ± 3	0 + 1.2
Trial 2	11 mm ± 0.7	0 mm ± 0.8	90° ± 5	0 + 1.2

Table 2 – Trial Setting

Settings	Parameter 2	Parameter 3	Parameter 6	Parameter 7
Standard	0.8	0.88	1.66	0.32
Trial 1	1.51	1.59	1.87	2.27
Trial 2	1.58	1.78	4.61	2.19

Table 3- Trial Settings Cpk

A generic programme was developed and implemented two weeks after new settings for the system. The result presented in figure 7 shows the increase in yield from 98.81% to 99.03%, as the result of this generic programme meeting the target set out at the start of the project. It took the technicians four weeks to be able to find optimum programme and the best possible result.

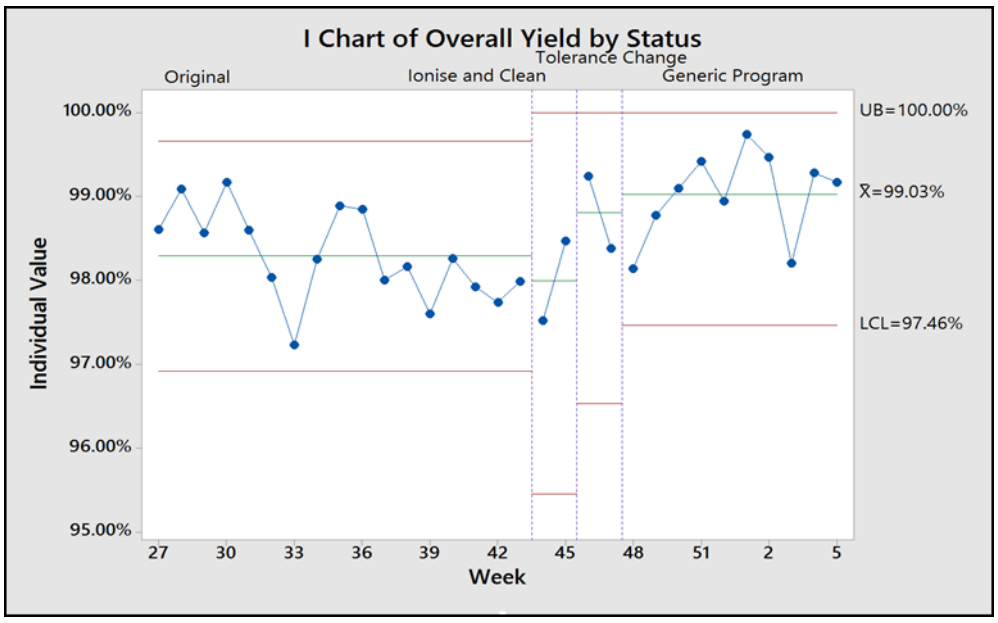


Figure 7 - Generic Vision Inspection Program Control Chart

Control

In order to control the process and retain the improvement in the FRY the clients' FMEA and control plans were updated with the changes made to the process. In addition to the FMEA and Control Plan, the control chart that was used through the previous four phases of DMAIC to identify the process performance has been upheld in order to be able to quickly identify any problems with the process.

5. Discussion and Conclusion Remarks

The main motivation behind using LSS methodology in this project was the existing LSS culture in the Company and also validity of the DMAIC methodology to reduce the variation and therefore scrape rate in the production line. The objective of the project has been attained, since the Vision Inspection process achieved an improvement in FRY from 98.3% to 99.03%, which exceeded the management target and represents sigma score from 3.65 to 3.85 and saving of £98k annually. The result of the project has been approved and was subjected to tollgate review by the project Champion. The result of this project could also be significant for the management team who have been planning to expand the production line and any process improvement in any scale would be critical for the managers. The saving could be greater in the future as the result of a possible plant expansion. The case study adds further evidence to the effectiveness of the LSS methodology in relation to waste reduction and cost saving in the manufacturing industry and in particular the electronics and automotive sections.

The analysis of the potential increments of identified factors would not have been completed due to the lack of a DoE. Therefore the Cpk for all trials and FRY may have had slightly different results compared to when the DoE is used, which is recommended to be considered in the future work. There could also be a possibility of skewness in the improve phase due to possible regular alteration of settings by the Overmould technicians without any record. In addition to this, the LSS implementation in this Company could be extended to other processes rather than just manufacturing and being fully controlled by the team in order to correctly gauge the effect of any changes made to the process. It is also recommended that the project could be extended to other issues in the Overmould process that were identified in the Define stage as major contributors to the scrap level experienced.

References

AlBliwi, S. Antony, J. Lim, S. A.; and Van der Wiele, T. (2014), "Critical failure factors of Lean Six Sigma: a systematic literature review", International Journal of Quality and Reliability management, Vol. 31 No. 9, pp. 1012-1030.

Algassem, F, Yang, Q. P. and Au, J. (2014), "Application of Lean Six Sigma principles to Food Distribution SMEs", American Academic and Scholarly Research Journal, Vol. 6 No. 4, pp. 251-258.

Antony, J. and Desai, D. A. (2009), "Assessing the status of Six Sigma implementation in the Indian industry", Management Research News, Vol. 32 No. 5, pp. 413-423.

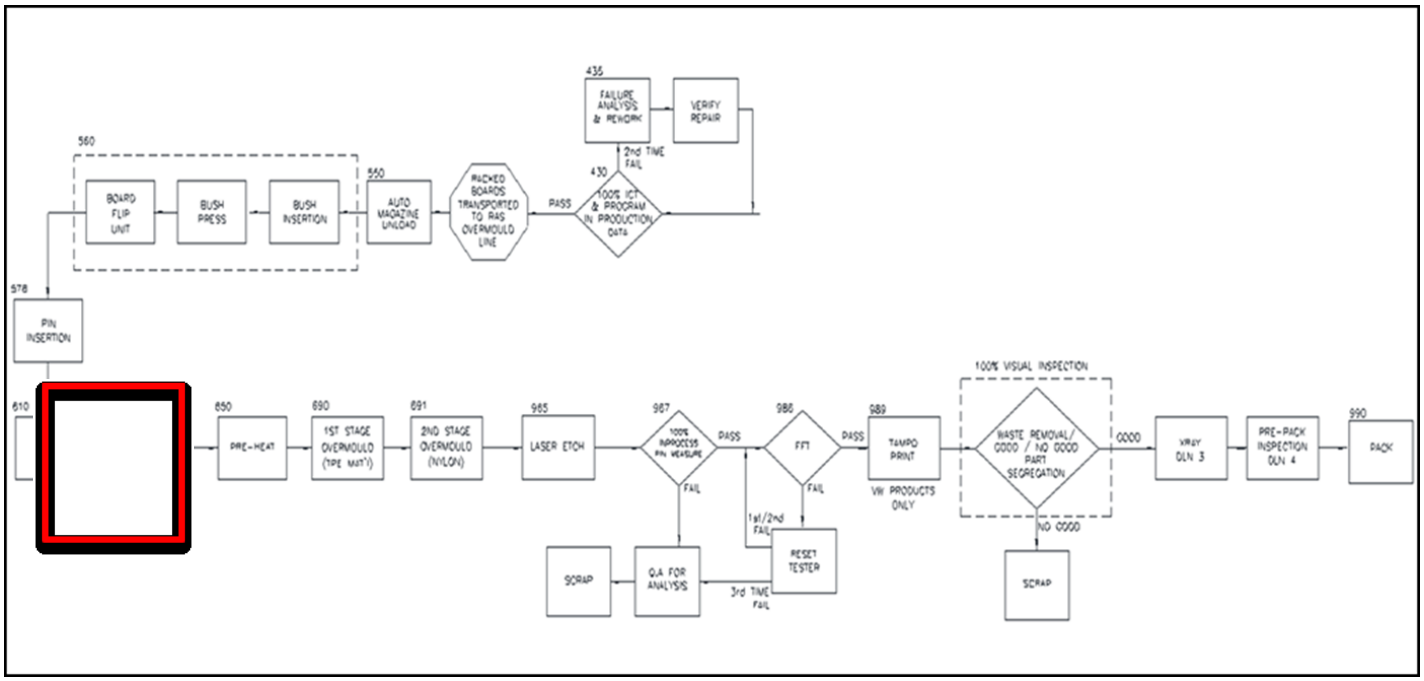
Antony, J., Kumar, M. and Madu, C.N. (2005), "Six Sigma in Small - and -medium sized UK manufacturing enterprises", International Journal of Quality & Reliability Management, Vol. 22 No. 8, pp. 860-874.

Assarlind, M. Gremyr, I. and Backman, K. (2013), “Multi-faceted views on a Lean Six Sigma application”, International Journal of Quality and Reliability Management, Vol. 30 No. 4, pp. 387-402.
Atmaca, E. and Girenes, S. (2013), “Lean Six Sigma methodology and application”, Qual Quant, Vol. 47, pp. 2107-2127.
Avison, D., Baskerville, R. and Myers, M. (2001) 'Controlling action research projects', Info Technology & People, 14(1), pp. 28-45.
Bamford, D. Forrester, P. Dehe, B, and Leese, R. G. (2015), “Partial and interative Lean implementation: two case studies”, International Journal of Operations and Production Management, Vol. 35 No. 5, pp. 702-727.
Bhat, S. Gijo, E.V. and Jnanesh, N. A. (2014), “Application of Lean Six Sigma methodology in the registration process of a hospital”, International Journal of Productivity and Performance Management, Vol. 63 No. 5, pp. 613-643.
Biranvand, A. and Khasseh, A. A. (2013), “Evaluating the service quality in the regional information centre for science and technology using the Six Sigma methodology”, Library management, Vol. 34 No. 1/2, pp. 56-67.
Brun, A. (2011), “Critical success factors of Six Sigma implementations in Italian companies”, International Journal of Production Economics, Vol. 131 No. 1, pp. 158-164.
Burton, T.T. (2011) Accelerating Lean Six Sigma Results. Ft. Lauderdale: J. Ross Publishing Inc.
Choi, B. Kim, J. Leem, B. Lee, C. Y. and Hong, H. K. (2012), “Empirical analysis of the relationship between Six Sigma management activities and corporate competitiveness”, International Journal of Operations and Production management, Vol. 32 No. 5, pp. 528-550.
Cournoyer, M. Nobile, A.O. Williams, G.M. Monsalve-Jones, RA. Renner, C.M. and George, G.L. (2013), “Application of lean six sigma business practices to an air purifying respiration process”, Journal of Chemical health and Safety, March/April.
Delgado, C. Ferreira, M. and Branco, M.C. (2010), “The implementation of lean Six Sigma in financial services organisations”, Journal of Manufacturing and Technology Management”, Vol. 21 No. 4, pp. 512-523.
Dora, M. and Gellynck, X. (2015), “Lean Six Sigma Implementation in a Food Processing SME: A Case Study”, Quality and Reliability Engineering International, Vol. 31 No. 7, pp. 1151-1159.
Gijo, E.V. Antony, J. Kumar, M. McAdam, R. and Hernandez, J. (2014), “An application of Six Sigma methodology for improving the first pass yield of a grinding process”, Journal of Manufacturing Technology management, Vol. 25 No. 1, pp. 125-135.
Gupta, V. Acharya, P. and Patwardhan, M. (2012), “Monitoring goals through lean six sigma insures competitiveness”, International Journal of Productivity and Performance Management, Vol. 61 No. 2, pp. 194-203.
Hilmola, O. Gupta, M. (2015), “Throughput accounting and performance of a manufacturing company under a stochastic demand and scrap rates”, Expert Systems with Applications, Vol. 42 NO. 22, pp. 8423-8431.
Hilton, R.J. and Sohal, A. (2012), “A conceptual model for the successful deployment of Lean Six Sigma”, International Journal fo Quality and Reliability management, Vol. 29 No. 1, pp. 54-70.
Holmes, M. C. Jenicke, L. O. Hempel, J. L. (2015), “A framework for Six Sigma project selection in higher educational institutions, using a weighted scorecard approach”, Quality Assurance in Education, Vol. 23 No. 1, pp. 30-46.
Isa, M. F. M. and Usmen, M. (2015), “Improving university facilities services using Lean Six Sigma: a case study”, Journal of Facilities Management, Vol. 13 No. 1, pp. 70-84.

Ismail, A. Chani, J. A. Ab Rahman, M. N. Md Deros, B. Hassan, C; and Haron, C. (2014), "Application of Lean Six Sigma Tools of Cycle Time Reduction in manufacturing: Case Study in Biopharmaceutical Industry", Arabian Journal for Science and Engineering, Vol. 39 No 2, pp. 1449-1463.
Jayaraman, K. Kee, T. L. and Soh, K. L. (2012), "The perceptions and perspectives of Lean Six Sigma (LSS) practitioners", The TQM Journal, Vol. 24 No. 5, pp. 433-446.
Kanpp, S. (2015), "Lean Six Sigma implementation and organisational culture", International Journal of health Care Quality Assurance, Vol. 28 No. 8, pp. 855-863.
Kumar, M., Antony, J. and Tiwari, M.K. (2011), "Six Sigma implementation framework for SMEs – a roadmap to manage and sustain the change", International Journal of Production research, Vol. 49 No.18, pp.5449-5467.
Kumar, M., Antony, J. and Douglas, A. (2009), "Does size matter for Six Sigma implementation?" The TQM journal, Vol. 21 No. 6, pp. 623-635.
Lee, T.Y., Wong, W.K. and Yeung, K.W. (2011), "Developing a readiness self-assessment model (RSM) for Six Sigma for China enterprises", International Journal of Quality and Reliability Management, Vol. 28 No. 2, pp. 169-194.
Manville, G. Greatbanks, R. Krishnasamy, R. and Parker, D. W. (2012), "Critical success factors for Lean Six Sigma programmes: a view from middle management", International Journal of Quality & Reliability Management, Vol. 29 No. 1, pp. 7-20.
Orbak, Â.Y. (2012), "Shell scrap reduction of foam production and lamination process in automotive industry", Total Quality Management & Business Excellence, Vol. 23 No. 3, pp. 325-341.
Prashar, A. (2014), "Adoption of Six Sigma DMAIC to reduce cost of poor quality", International Journal of Productivity and Performance Management, Vol. 63 No. 1, pp. 103-126.
Sarkar, S. A. Mukhopadhyay, A. R. and Ghosh, A. K. (2013), "Root cause analysis, Lean Six Sigma and test of hypothesis", The TQM Journal, Vol. 25 No. 2, pp. 170-185.
Saunders, M. Lewis, P. and Thornhill, A. (2012), "Research methodologies for business students", Pearson Financial Times, Second Edition, Essex, UK.
Shafer, S.M. Moeller, S.B. (2012), "The effects of Six Sigma on corporate performance: An empirical investigation", Journal of Operations Management, Vol. 30, pp. 521-532.
Thomas, A. Barton, R. and Chuke-Okafor, C. (2009), "Applying lean six sigma in a small engineering company – a model for change", International Journal of Manufacturing Technology management, Vol. 20, No.1, pp. 113-129.
Timans, W. Antony, A. Ahaus, K. and Van Solingen, R. (2012), "Implementation of Lean Six Sigma in small- and medium – sized manufacturing enterprises in the Netherlands", International Journal of the Operational research Society, Vol. 63 No. 3, pp. 339-353.
Tyagi, S., Choudhary, A., Cai, X. and Yang, K. (2015) 'Value stream mapping to reduce the lead-time of a product development process', International Journal of Production Economics, 160(0), pp. 202-212.
Wang, F. K. and Chen, K. (2012), "Application of Lean Six Sigma to a panel equipment manufacturer", Total Quality management, Vol. 23 no. 4, pp. 417-429.
Worley, J. M. and Doolen, T. L. (2015), "organisational structure, employee problem solving and lean implementation", International Journal of Lean Six Sigma, Vol. 6 No. 1, pp. 39-58.

Appendices

Appendix A



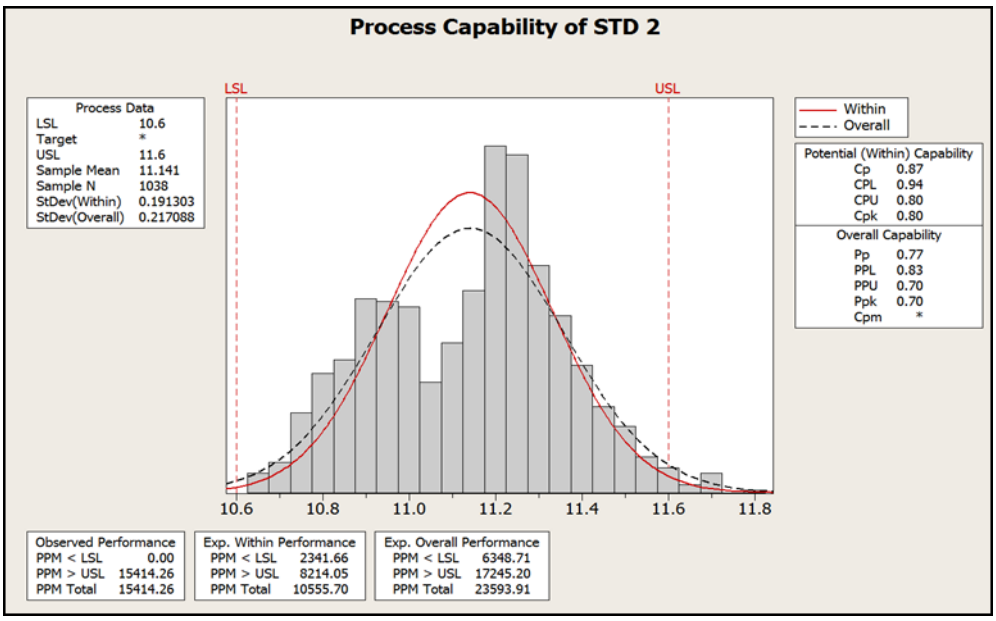
High Level Process Map

Appendix B

Project Details					
Scope	Start: Stop: Includes: Excludes:	OP 620 OP620 All Overmould Products Other Products			
Project Goals	**Metric**	**Baseline**	**Current**	**Goal**	**Entitlement**
FRY	%	98.4%	98.4%	99%	0
Process Sigma Score/ DPMO	Values	3.65/ 15884	3.65/ 15884	3.85/9461	0
Expected Business Results	Increased FRY, reduction in scrap.				
Expected Customer Benefits	Improved throughput				
Team members	Gareth Bradley Black Belt 2x Green Belt 1x Business Unit Leader 1x Process Owner				
Support Required	Engineering Department (RAS/DAS) Production				
Risks or Constraints	Line Time, Support from other departments.				

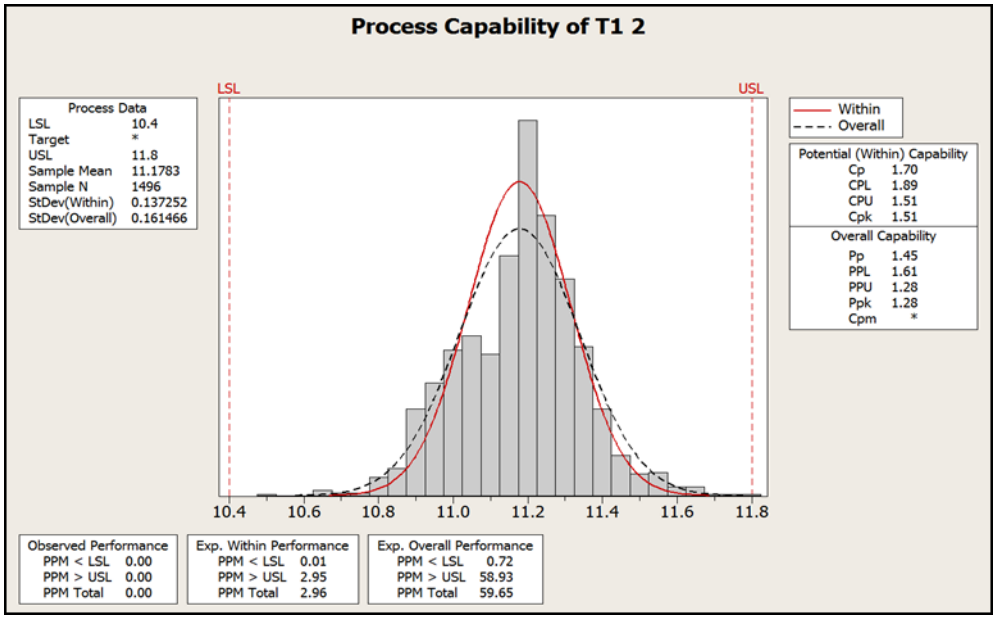
Project Charter Details

Appendix C



Parameter 2 Process Capability Normal Distribution

Appendix D



Trial 1 Parameter 2 Process Capability Normal Distribution