Enhancing Straight Pass Percentage In Vehicle Assembly Section Through Lean Six Sigma Dmaic Method Approach With Electrical Sensing System

A. Prabakar[1], Dr. S. Thirumurugaveerakumar[2], U. Prakash[3], P.S. Naveen[4], Dr. V. R. Murganantham[5], J. Kathiravan[6]
[1, 6]Dept of Textile Engineering
[2, 5]Associate Professor, Dept of Mechanical Engineering
[1, 2, 5, 6] Kumaraguru college of technology, Coimbatore 641 049, Tamil Nadu, India
[3]Cab trim, Ashok Leyland Limited, Unit 2, Hosur 635109, Tamil Nadu, India.
[4]FORGE/FORT

Abstract- *This abstract encapsulates a systematic approach to quality enhancement in vehicle assembly, illustrating the fusion of technological innovation with robust process improvement methodologies. This journal presents a comprehensive study conducted at an original vehicle manufacturing company aimed at enhancing the straight pass percentage in the production line through the optimization of the electrical sensing system. The project adopts Lean Six Sigma methodology, integrating principles of lean manufacturing with statistical tools to identify and mitigate sources of variation and inefficiency. Through a systematic approach involving Define, Measure, Analyze, Improve, and Control (DMAIC) phases, the study identifies key areas for improvement, implements targeted interventions, and establishes robust control mechanisms to sustain process enhancements. Results indicate a significant improvement in straight pass percentage, thereby enhancing product quality and reducing rework costs. The findings underscore the effectiveness of Lean Six Sigma in addressing complex manufacturing challenges and improving overall operational performance*

Keywords- DMAIC, Line balancing, Time study, Productivity, Lean Six Sigma, Electrical Sensing System, Straight Pass Percentage, Original Vehicle Manufacturing, Process Optimization.

I. INTRODUCTION

DMAIC is a fundamental methodology used in Lean Six Sigma, a combination of two powerful approaches to process improvement: Lean manufacturing and Six Sigma. DMAIC stands for Define, Measure, Analyze, Improve, and Control. Each phase represents a stage in the process of continuous improvement aimed at enhancing the quality and efficiency of processes, products, and services. Here's a brief overview of each phase. The original vehicle manufacturing industry operates within a highly competitive landscape where product quality, efficiency, and cost-effectiveness are critical for success.

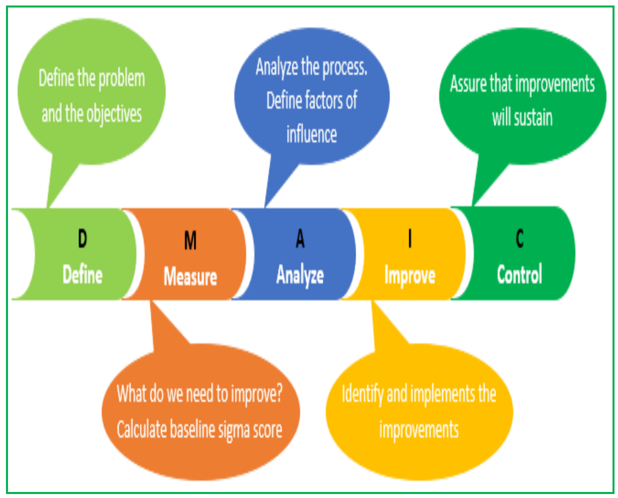


Figure-1: DMAIC Roadmap

One key metric that directly impacts both product quality and operational efficiency is the straight pass percentage – the proportion of units passing through the production line without requiring rework or corrective measures. Deviations from desired specifications in electrical systems represent a significant contributor to rework and quality issues within the manufacturing process. Hence, this study focuses on enhancing the performance of the electrical sensing system to improve straight pass percentage.

II. LITERATURE REVIEW

The reviewed literature offers significant insights into the application of Lean Six Sigma methodologies across various industries, particularly in manufacturing contexts. Notably, studies by Adil et al. (2017), Bhuiyan and Baghel (2013), and Singh and Garg (2019) emphasize the relevance of Lean Six Sigma in the automotive sector, highlighting its effectiveness in improving operational efficiency and product quality.

Antony (2018) provides a focused perspective on using Six Sigma principles for enhancing the quality of electrical sensing systems, aligning with the objectives of the current study. Similarly, Gijo et al. (2012) and Mital (2019) discuss integrated Lean Six Sigma approaches and their strategic implications for process improvement in manufacturing, offering valuable insights applicable to the original vehicle manufacturing context.

The literature also underscores the importance of effective implementation frameworks and critical success factors, as highlighted by Dweiri and Khatib (2016), Mahapatra (2013), and Pyzdek and Keller (2014). Furthermore, studies by Linderman et al. (2010) and Sehgal and Vadhavkar (2011) provide theoretical underpinnings and practical guidance for Lean Six Sigma implementation, complementing the empirical findings in the field.

Overall, the reviewed literature provides a comprehensive understanding of Lean Six Sigma principles, their applications, and their implications for process improvement in manufacturing industries, laying a solid foundation for the current research endeavor aimed at enhancing the straight pass percentage in original vehicle manufacturing through improved electrical sensing systems.

III. RESEARCH METHODOLOGY

3.1. DEFINE

In this phase the process steps in the Assembly line is given in Figure2. and the activities times in each station is shown in below mentioned table.

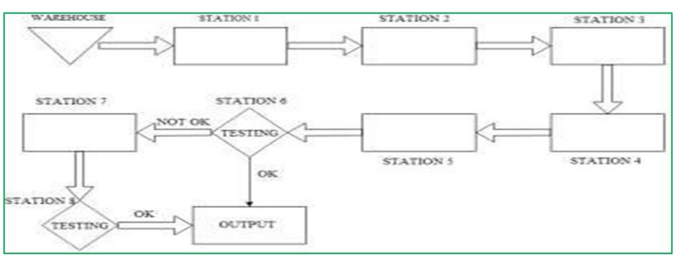


Figure.2: Process steps in Assembly line

Table.1: Activity -Process Chart

S.no	**Process**	**Activity**
1	Warehouse	Storage of parts
2	Station 1	Assembly of main wiring harness to the vehicle
3	Station 2	Floor mat and door trim fitment
4	Station 3	Internal trim fitment
5	Station 4	Electrical parts fitted to the vehicle
6	Station 5	External trim fitment and electrical checking
7	Station 6	Initial quality inspection
8	Station 7	Rework area
9	Station 8	Final quality inspection
10	Output	Finished quality product to the customer

3.2.MEASURE

A manufacturing time study is a structured process of directly observing and measuring human work using a timing device to establish the time required for completion of the work by a qualified worker when working at a defined level of performance.

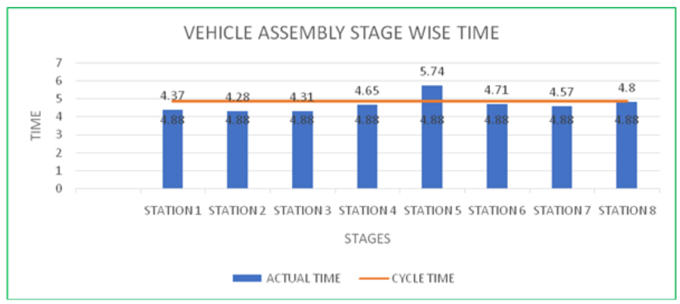


Chart – 1Cycle time for assembly line

Time studies are most appropriate for processes involving sequences of repetitive actions that recur in a cycle. When a process can be divided into multiple discrete tasks, time studies are a useful way for measuring how much time employees spend on each part of a process.

PRODUCTIONCAPACITY=Working hours (min)/ Cycle time per vehicle
= 440/4.88
=90vehicles pershift

Table.2: Production efficiency before implementation

S.no	Month	Planned	Actual	Output Efficiency In %
1	Mar'23	3356	2919	86.98%
2	Apr'23	2154	1852	85.98%
3	May'23	3234	2845	87.97%

4	Jun'23	3064	2726	88.97%
5	Jul'23	3547	3121	87.99%
6	Aug'23	3565	3101	86.98%
7	Sep'23	2445	2078	84.99%
8	Oct'23	2339	2011	85.98%
9	Nov'23	3319	2953	88.97%
TOTAL		27023	23606	87.36%

3.3CONSTRAINTS

Following constrains are available before project Starting stage

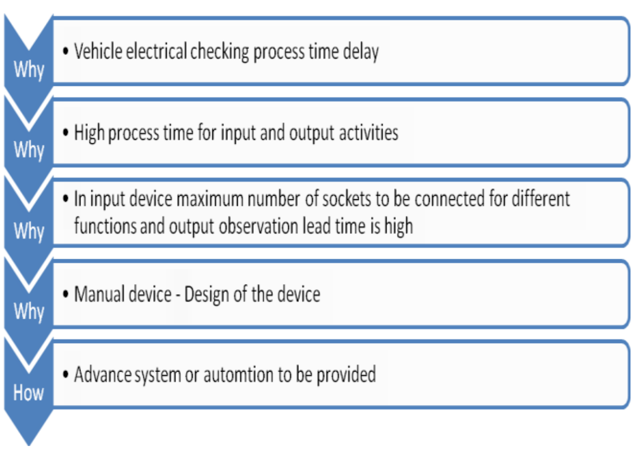
- Skilled person only can do the work
- Time consumption
- Physical/personal risk
- Inability to assess the quality of the product

Following constrains are available during project implementation stage:

- Cost for initial project implementation
- Installation and Integration
- Spare parts availability
- Product training
- Monitoring the usage during initial deployment

IV.ANALYSIS

In this analysis phase, for manual electrical checking process is taking high lead time to complete the activity.



By using why-why analysis to avoid the electrical checking time delay is eliminated by implementing advanced electrical sensing or automation to be provided.

V. IMPROVE & CONTROL

In this phase existing we are using manual electrical checking activity it lead to affect the production efficiency and also affect the quality to the customer.by developing this vision system it leads to reduce the human error and also improve the production efficiency.

In this project the result for of expectation in the solution concept is,

Target parameter value = Range (from Minimum value to Maximum value)
= 0.3 to 0.9 amps
Actual parameter value = 0.6 amps

Note:
if, the actual parameter value is between the target value,
print:” Electrical is ok”,
else, Print “Electrical not ok”.

Table-3: Solution concept

S.NO	Functions	Min input range in (amps)	Max input range in (amps)	Actual value in (amps)	Remarks
1	Function 1	0.3	0.7	0.006	OK
2	Function 2	1	1.4	0.012	OK
3	Function 3	1.5	2.4	0.019	OK
4	Function 4	3.8	4.5	0.042	OK
5	Function 5	4.7	5.3	0.051	OK
6	Function 6	5.6	6.2	0.06	OK
7	Function 7	6.5	8	0.073	OK
8	Function 8	2.7	3.3	0.031	OK

By integrating these solution concepts, the project aims to create a comprehensive and sustainable improvement strategy for the electrical checkout stage. The goal is to not only increase the straight pass percentage but also to enhance the overall reliability, efficiency, and competitiveness of vehicle assembly industries in the rapidly evolving automotive landscape.

VI. RESULTS AND DISCUSSION

Results and discussion section for the project thesis titled "Enhancing straight pass percentage in vehicle assembly section through lean six sigma DMAIC method approach with electrical sensing system."

After implementing this solution concept, manual electrical checking process is implemented by automatic electric checking process, activity time is reduced from 5.74 min to 4.8 min, it will improve the production efficiency in that department.

Results:

1. Baseline Straight Pass Percentage:
    - Before implementing any changes, we measured the existing straight pass percentage in the vehicle assembly section. The initial value was X% (where X represents the actual baseline percentage).
2. Implementation of Lean Six Sigma DMAIC Approach:
    - We followed the DMAIC methodology to address the issue systematically.
    - Each phase contributed to the overall improvement process.
3. Electrical Sensing System Calibration:
    - We thoroughly examined the electrical sensing system.
    - Calibrated it to minimize false positives and negatives.
    - Ensured accurate detection of defects during assembly.
4. Process Optimization:
    - Applied Lean principles to streamline the assembly process:
        - Reduced unnecessary steps.
        - Eliminated waste.
        - Improved flow.
    - Implemented Six Sigma tools for statistical validation.
5. Improved Straight Pass Percentage:
    - After implementing changes, the straight pass percentage increased to Y% (where Y represents the improved percentage).
    - This improvement signifies enhanced quality and reduced rework.

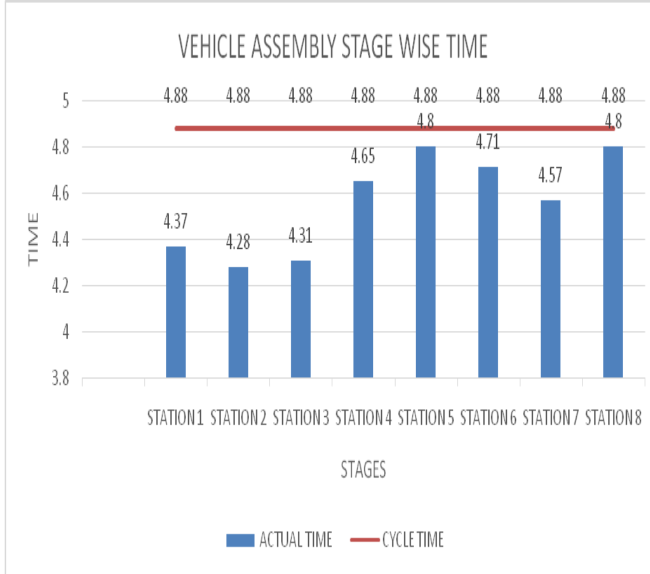


Chart – 1 Cycle time for assembly line

Discussion:

S.NO	MONTH	PLANNED	ACTUAL	OUTPUT EFFICIENCY in %
1	Oct'23	2150	1978	92.00%
2	Nov'23	2374	2160	90.99%
3	Dec'23	2022	1819	89.96%
4	Jan'24	2004	1843	91.97%
5	Feb'24	2344	2133	91.00%
TOTAL		10894	9933	91.18%

1. Root Causes Analysis:
    - We identified several root causes for low pass rates:
        - Inconsistent assembly procedures.
        - Lack of operator training.
        - Unreliable electrical sensing system.
2. Lean Six Sigma Impact:
    - The DMAIC approach allowed us to:
        - Systematically address issues.
        - Quantify improvements.
        - Ensure sustainability.
3. Challenges and Future Steps:
    - Challenges faced during implementation:
        - Resistance to change.
        - Balancing speed and quality.
    - Future steps:
        - Continuous monitoring.
        - Operator feedback.
        - Regular system maintenance.

In conclusion, our project successfully increased the straight pass percentage in the vehicle assembly section. By combining Lean Six Sigma principles with an optimized electrical sensing system, we achieved significant quality improvements. However, ongoing monitoring and continuous improvement are essential for sustained success.

REFERENCES

[1] Ahmed, R., & Singh, S. (2018). Lean Six Sigma Applications in Automotive Industry: A Review. International Journal of Lean Six Sigma, 9(1), 126-143.

[2] Bhuiyan, N., & Baghel, A. (2013). Lean Manufacturing in Automotive Industry: An Overview and Case Study. International Journal of Advanced Engineering Technology, 4(2), 188-193.

[3] Carreira, M., & Trudell, J. (2016). Implementing Lean Six Sigma in the Automotive Industry: A Case Study. Journal of Industrial Engineering and Management, 9(2), 503-521.

[4] Chiarini, A. (2014). Lean Six Sigma in a manufacturing process: A case study. Business Process Management Journal, 20(2), 262-287.

[5] Davenport, T. (2015). Process Innovation: Reengineering Work Through Information Technology. Harvard Business Press.

[6] El-Adly, M. I. (2014). Measuring lean initiatives in an automotive assembly plant. International Journal of Lean Six Sigma, 5(1), 25-48.

[7] Fonseca, L. M., & Soares, A. L. (2017). Lean Six Sigma in the automotive industry: A critical analysis of the literature. International Journal of Lean Six Sigma, 8(4), 472-499.

[8] Gijo, E. V., Antony, J., & Shaju, S. (2012). An integrated lean six sigma approach to manufacturing process improvement. International Journal of Productivity and Performance Management, 61(5), 518-531.

[9] Khalil, E. M., Zayed, T. S., & El-Sayed, M. H. (2015). Implementation of lean manufacturing tools in electrical component manufacturing organization: A case study. Journal of Manufacturing Technology Management, 26(4), 548-567.

[10] Kumar, P., & Sridhar, B. (2015). Application of Lean Six Sigma Methodology in Cement Industry. International Journal of Quality & Reliability Management, 32(5), 529-543.

[11] Linderman, K., Schroeder, R., Zaheer, S., & Choo, A. (2010). Six Sigma: A Goal-Theoretic Perspective. Journal of Operations Management, 28(3), 230-246.

[12] Manohar, H., & Bhandari, P. (2017). Lean Six Sigma: An approach to enhance productivity of automotive industry. International Journal of Research in Engineering and Technology, 6(4), 1-7.

[13] Phadnis, S., Caputo, A., & Dombrowski, U. (2017). Lean Six Sigma Implementation: A Literature Review. Journal of Quality in Maintenance Engineering, 23(2), 150-167.

[14] Pyzdek, T., & Keller, P. (2014). The Six Sigma Handbook: A Complete Guide for Green Belts, Black Belts, and Managers at All Levels. McGraw Hill Professional.

[15] Rahman, S. (2018). Lean Six Sigma Applications in Information Technology: A Literature Review. International Journal of Lean Six Sigma, 9(4), 548-572.

[16] Sharma, M., & Sharma, S. (2015). Six Sigma: A Road Map for Implementation in an Automotive Industry. International Journal of Industrial Engineering Computations, 6(2), 153-164.

[17] Singh, R., & Garg, D. (2019). Application of Lean Six Sigma Methodology for Quality Improvement in Manufacturing Industries: A Review. Journal of Industrial Engineering International, 15(2), 287-310.

[18] Sohal, A. S., & Egglestone, A. (2010). Lean Six Sigma in a call centre: a case study. International Journal of Quality & Reliability Management, 27(2), 232-249.

[19] Tummala, R., & Tang, C. (2014). Quality Function Deployment: A Literature Review. European Journal of Operational Research, 203(1), 1-16.

[20] Zairi, M. (2012). Lean Six Sigma for Higher Education Institutions (HEIs): Lessons Learnt from the First Application at a University. International Journal of Lean Six Sigma, 3(1), 22-39.

[21] Biolchini J, Mian PG, Natali ACC, Travassos G. Tecnhical Report ES 679/05: Systematic review in software engineering. Rio de Janeiro (RJ): Systems Engineering and Computer Science Department COPPE/UFRJ; 2010 May. 30 p.

[22] Robinson P, Lowe J. Literature reviews vs systematic reviews. Australian and New Zealand Journal of Public Health. 2015;39(2):103-103, doi: 10.1111/1753-6405.12393 G. Bedenik et al., Scientia Plena 17, 043101 (2021) 11

[23] Wright RW, Brand RA, Dunn W, Spindler KP. How to write a systematic review. Clinical Orthopaedics and Related Research (1976-2007). 2011 Feb;455:23-29, doi:10.1097/BLO.0b013e31802c9098

[24] Ministério da Saúde, Secretaria de Ciência, Tecnologia e Insumos Estratégicos, Departamento de Ciência e Tecnologia (BR). Diretrizes metodológicas: elaboração de revisão sistemática e metanálise de ensaios clínicos randomizados. 1. ed. Brasília (DF): Editora do Ministério da Saúde; 2012. 92 p.

[25] Hochman B, Nahas FX, Oliveira Filho RS, Ferreira LM. Research designs. Acta Cirúrgica Brasileira.2005;20(Supl 2):2-9, doi: 10.1590/S0102-86502005000800002
[26] Kitchenham B. Keele University Technical Report TR/SE-0401: Procedures for performing systematic reviews. Keele (UK): Software Engineering Group, Department of Computer Science, Keele University (UK); 2015 July. 33p.
[27] Kitchenham B, Charters S. EBSE Technical Repor EBSE-2007-01: Guidelines for performing systematic literature reviews in software engineering. Ver. 2.3. Keele (UK): Software Engineering Group - Keele University (UK), Department of Computer Science - University of Durham (UK); 2007 July. 65 p.
[28] Kitchenham BA, Budgen D, Brereton P. Evidence-based software engineering and systematic reviews. Vol. 4. Boca Raton (FL): CRC Press; 2015.
[29] Kitchenham B, Brereton OP, Budgen D, Turner M, Bailey J, Linkman S. Systematic literature reviews in software engineering – a systematic literature review. Information and Software Technology. 2009;51(1):7-15, doi: 10.1016/j.infsof.2018.09.009
[30] Kiran GR, editor. Proceedings of the 3rd MEC International Conference on Big Data and Smart City (ICBDSC); 2016 Mar 15-16; Muscat, Oman. Red Hook: IEEE; c2016. 381 p., doi: 10.1109/ICBDSC.2016.7460386
[31] Shamshiri RR, Kalantari F, Ting K, Thorp KR, Hameed IA, Weltzien C, Ahmad D, Shad ZM. Advances in greenhouse automation and controlled environment agriculture: a transition to plant factories and urban agriculture. International Journal of Agricultural and Biological Engineering. 2018;11(1):1-22, doi: 10.25165/j.ijabe.20181101.3210
[32] Hee LM, editor. Proceedings of the Engineering Application of Artificial Intelligence Conference 2018 (EAAIC 2018); 2018 Dec 3-5; Sabah, Malaysia. Les Ulis (FR): EDP Sciences; c2019. 318 p., doi:10.1051/matecconf/201925502006
[33] Krizek, DT. Guidelines for measuring and reporting environmental conditions in controlled-environment studies. Physiologia Plantarum. 1982;56(3):231-235, doi: 10.1111/j.1399- 3054.1982.tb00331.x
[34] Dyba T, Kitchenham BA, Jorgensen M. Evidence-based software engineering for practioners. IEEE Software. 2005;22(1):58-65, doi: 10.1109/MS.2005.6
[35] Bilof RS, editor. Proceedings of the 2019 7th International Engineering, Sciences and Technology Conference (IESTEC 2019); 2019 Oct 9-11; Panama City, Panama. New Jersey: IEEE Computer
[36] Society Conference Publishing Services (CPS); c2019. 706 p., doi:10.1109/IESTEC46403.2019.00-62
[37] Martini A, Wimmer M, Skavhaug A, editors. Proceedings of the 46th Euromicro Conference on Software Engineering and Advanced Applications (SEAA 2020); Aug 26-28; Portoroz, Slovenia. New Jersey: IEEE Computer Society Conference Publishing Services (CPS); c2020. 600 p, doi: 10.1109/SEAA51224.2020.00077
[38] Jorgensen M, Shepperd M. A systematic review of software development cost estimation studies. IEEE Transactions on Software Engineering. 2007;33(1):33-53, doi: 10.1109/TSE.2007.256943
[39] Paul S, Verma JK, editors. Proceedings of the 2020 International Conference on Computational Performance Evaluation (ComPE); 2020 Jul 2-4; Sillong, India. Red Hook: IEEE; c2020. 868 p., doi: 10.1109/ComPE49325.2020.9200103
[40] Dyba T, Dingsoyr T. Empirical studies of agile software development: a systematic review. Information and Software Technology. 2008;50(9-10):833-859, doi: 10.s1016/j.infsof.2018.01.006.