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Sustainable Process Improvement Through Six Sigma in a Glass Manufacturing Environment

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***Abstract*— In the competitive environment of the 21st century, organizations need cutting edge techniques to maintain their sustainability. Six Sigma is widely used by the process industries to optimize their performance and improve their profitability. The present research aims to improve the productivity of a glass manufacturing environment by optimizing their processes. In this regard, historical data from the knowledge repositories has been scrutinized against the parameters of production efficiency, inspection losses, major breakdowns, held ware, critical defects, and customer complaints, while the Six Sigma tools of the fishbone diagram, cause and effect matrix, Pareto analysis, and failure mode effect analysis (FMEA) are used for the purpose of data analysis. Findings revealed a process variation between the current and the targeted performance. Based on the findings of DMAIC approach, significant factors affecting the glass manufacturing industry are identified. The process has seen an improvement in 2020 as compared to 2019 by 6%. Moreover, a preventive maintenance plan of ManWinwin software has been installed as a preventative measure and resultantly, the breakdown percentage is also reduced by 2%. It is observed that better cooperation and communication between different departments can further lead to productivity enhancement.*

***Keywords*— Six Sigma, DMAIC, FMEA , KPI , Pareto Chart , Fishbone.**

I. INTRODUCTION

The growing competition within the current global market is difficulty translating into an unlimited need for the industry's continuing evolution. Therefore, world business is continually looking for a competitive edge because of the growing demands of customer needs and expectations. Quality has a significant role within the business process across the whole organization, to be more efficient and effective within the global market, thus improving productivity and customer loyalty furthermore as an increasing market share.[1]

The production of glass containers is a very complex and demanding procedure that has to be very well equipped and optimally adjusted to produce glass containers that satisfy even the most demanding customers while being competitive on the market. Glass containers have to be maximally light, as well as less expensive. At the same time, they have to withstand maximal mechanical loads, greater internal pressure, thermal shocks (pasteurization), etc. to be able to meet these requirements, improving the quality of glass containers and increased production lines productivity with machines operates 24 hours a day, seven days a week.[2]

A . Six Sigma Definitions

Six Sigma is a management philosophy to systematically reduce variations and improve processes' quality. The concept is widely used in most organizations centered on process improvements and quality initiatives in a sustainable way. Based on an extensive literature review, the following tenets of Six Sigma are identified.[3]

Six Sigma as a metric: Metric definition of Six Sigma is widely recognized as 3.4 DPMO to achieve high quality among products and services delivered to the customers. Six Sigma's metric purpose is based on treating variation as evil to achieve a higher quality level. Six Sigma approach focuses on reducing variation so much that there is 6σ distance between the process target and nearest specification limit [4]

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Six Sigma is a methodology: Improving quality requires a phase-based process management structure that supports high-quality end product or service standards. Six Sigma follows a structured DMAIC (Define-Measure-Analyze-Improve-Control) methodology to streamline quality improvement efforts. Though promoted under the umbrella of Six Sigma, DMAIC is the generic improvement methodology that can be applied anywhere [5]

Six Sigma as a set of statistical tools: One of the reasons that DMAIC is so successful is that it focuses on the effective use of statistical tools. Guidelines for using statistical tools based on different DMAIC methodology phases are proposed by Muralidharan and Hahn. [6]

Six Sigma as a management philosophy: Genetic code of Six Sigma goes well beyond metric definition and DMAIC methodology of Six Sigma. Since Six Sigma evolves from statistical quality control, scientific management, and quality engineering, it is based on core scientific principles instead of rhetoric.[7]

B . The Six Sigma History

Six Sigma's roots as a measurement standard can be traced back to Carl Friedrich Gauss (1777-1855), who introduced the normal curve concept. Six Sigma as a measurement standard in product variation can be traced back to the 1920s when Walter Shewhart showed that three sigma from the mean is when a process requires correction. Many measurement standards (Cpk, Zero Defects, etc.) later came on the scene, but credit for coining the term "Six Sigma" goes to a Motorola engineer named Bill Smith. (Incidentally, "Six Sigma" is a federally registered trademark of Motorola).[8]

In the early and mid-1980s, with Chairman Bob Galvin at the helm, Motorola engineers decided that the traditional quality levels — measuring defects in thousands of opportunities – didn't provide enough granularity. Instead, they wanted to measure the defects per million opportunities. Motorola developed this new standard and created the methodology and needed cultural change associated with it. Six Sigma helped Motorola realize powerful bottom-line results in their organization – in fact, they documented more than $16 Billion in savings due to our Six Sigma efforts.[9]

Since then, tens of thousands of companies worldwide have adopted Six Sigma as a way of doing business. This is a direct result of many of America's leaders openly praising the benefits of Six Sigma. Leaders such as Larry Bossidy of Allied Signal (now Honeywell), and Jack Welch of General Electric Company. Rumor has it that Larry and Jack were playing golf one day, and Jack bet Larry could implement Six Sigma faster and with greater results at GE than Larry did at Allied Signal. The results speak for themselves.[10]

Table 1: The Six Sigma History

1777-1855	The basis of the normal curve was established by Carl Frederick Gauss.
1986	Bill Smith evolved Six Sigma in Motorola Company.
1988	Motorola won the Malcolm Bold ridge National Quality Award as the first ever company.
1993	Six Sigma was taken up by Allied.
1995	General electronic started the concept of Six Sigma.
1998	Six Sigma was accepted by Honeywell.
2000	Six Sigma was endorsed by Ford

C . Objective

Study the process variation to identify the gaps between current performance and glass manufacturing KPI for improving, controlling, and achieving the process's stability.

D. Problem Statment

The Problem statement and the reason for doing this study are to define a sustainable process improvement by using Six Sigma tools to identify the variation in the process and factors will affect the stability. This study could be implemented in different private and public sectors, large and small organizations. This study was implemented in A Glass Manufacturing Company, one of the biggest companies producing glass in the middle east. This study was implemented in the short term, six months to one year. A Glass Manufacturing Company needs to improve internal processes to increase efficiency, improve productivity, and reduce wastage of time and cost. There is strong competition in the local and external markets, and the Company needs to be on the same track and keep improving.

II. METHODOLOGY

The methodology used was based on DMAIC, with the following stages: Define, Measure, Analyze, Improve and Control. For each stage, Lean Six Sigma techniques, such as Project Charter, Data Collection Plan, Cause and Effect Diagram. Failure mode effects analysis (FMEA), Pareto Chart, implementation plan and Monitoring-Response-Plan

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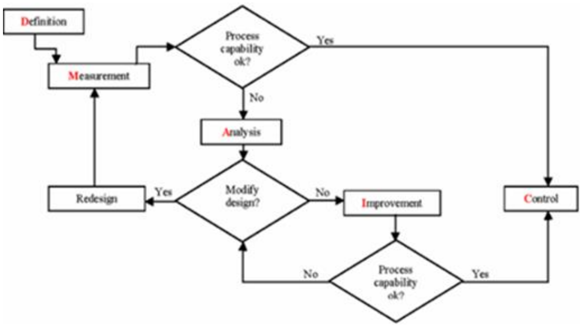

Fig.1: Six Sigma DMAIC information flow

A. Defined

Define is the first phase of the Lean Six Sigma improvement process. During this phase, the project team drafts a Project Charter, plots a high-level map of the process and clarifies customers' needs. By conducting Process Walks and talking to process participants, they begin building their process knowledge. Before moving on to the Measure Phase, the team refines its project focus and ensures they are aligned with organizational leadership goals. Applying project charter for outlines the presenting problem, the target, and the boundaries of a process improvement effort.

B. Mesure

Measurement is critical throughout the project's life since it provides critical indicators of process health and clues to where process issues are happening. As the team collects data, they focus on the lead time of the process or the quality of what customers are receiving. Before moving on to the Analyze Phase, the team defines its measures and determines the current performance or the process's baseline.

Data is one of the most valuable resources today's businesses have. The more information and records you have about your process, the better you can understand your process, wants, and needs. This enhanced understanding helps you meet and exceed your customers' expectations and allows you to create messaging and products that appeal to them.

C. Analysis

the data will give you all the information and based on that information; you will know how to proceed. It is working smart without guessing or using the luck of the draw, this chapter provides the analysis of data and results using Microsoft Excel and Six sigma technicians to identify and analyze our data that affect the stability of the process.

In this phase, you will do data and process analysis and measure the gap preventing you from your goal performance. This will automatically lead you to do a root cause analysis.

This study aims to investigate and find out what are the causes that can affect the stability of the process and what are the root causes.

A cause and effect diagram examine why something happened or might happen by organizing potential causes into smaller categories. It can also be useful for showing relationships between contributing factors. One of the Seven Basic Tools of Quality is often referred to as a fishbone diagram or Ishikawa diagram.[11]

After using cause and effect diagram we used failure modes and effects analysis (FMEA) is a step-by-step approach for identifying all possible failures in a design, a manufacturing or assembly process, or a product service.

"Failure modes" means the ways, or modes, in which something might fail. Failures are any errors or defects, especially ones that affect the customer and can be potential.

"Effects analysis" refers to studying the consequences of those failures.

Failures are prioritized according to how severe their consequences are, how frequently they occur, and how easily they can be detected. The purpose of the FMEA is to take actions to eliminate or reduce failures, starting with the highest-priority ones.[12]

After Reviewing our causes and effect diagram and labeling Process Steps and the intended function or functions of those steps, we have Considered the Potential Failure Modes for each component and its corresponding function. We Determine the Potential Failure Effects associated with each failure mode. The effect is related directly to the ability of that specific component to perform its intended function. For each failure mode, we have determined all the Potential Root Causes then For each cause. We identified the Current Process Controls. These are tests, procedures, or mechanisms that you now have in place to keep failures from reaching the customer then Assign a Severity Ranking to each effect that has been identified, Occurrence, and Detection.

Calculate the Risk Priority Number (RPN), which gives us a relative risk ranking. The higher the RPN, the higher the potential risk. it's calculated by multiplying the three rankings together (Severity x Occurrence x Detection) then we can take the decision to select the highest RPN to Develop an Action Plan for improvement and Taking action means reducing the RPN. The RPN can be reduced by lowering any of the three rankings (severity, occurrence, or detection) individually or in combination with one another.[13]

The Pareto principle, also known as the 80-20 rule, derived from the Italian economist Vilfredo Pareto's observations about the factor of sparsity, which states that 80% of the effects are coming from 20% of the causes.it will help us into patronize the top causes of our problem and focusing on the most significant[14]

D. Improve

Once they have determined what is causing the problem, it is time for the team to implement plans to resolve the root cause(s). The Improve Phase is where the team refines their countermeasure ideas, pilots process changes, implements solutions, and collects data to confirm measurable improvement. A structured improvement effort can lead to innovative and elegant changes that improve the baseline measure and, ultimately, the customer experience.

Ford Motor Company introduced team Oriented problem-solving or 8D problem-solving methodology in early 1980 (Shafeek, 2018). The 8D was designed to tackle problems that arise in the industrial environment. The objectives of 8D are to identify the root cause of the problem with team effort, implement temporary action to eliminate waste and losses, and a permanent move to avoid reoccurrence and hidden costs. Henceforth, the 8D has become very popular among customers and suppliers because it is useful and reasonably easy to teach to perform systematic analysis to solve an error in the industrial environment.[15]

E. Control

How do we sustain the improvement? With improvements in place and the process problem fixed, the team must maintain the gains and make it easy to update best practices. In the Control Phase, the team develops a Monitoring Plan to track the updated process's success and crafts a Response Plan in case there is a dip in performance. Once in place, the Process Owner monitors and continually updates the current best method[16]

A Monitoring Plan is a data collection plan for checking the ongoing health of the improved process. It lists the measure, the targets for each measure, how each measure will be checked, how, and who will check the measures. It sets the stage for the Response Plan.

The Response Plan establishes a threshold or trigger level for each measure in the Monitoring Plan. When the process performance goes beyond a trigger level, the Response Plan details immediate and long-term actions that will help the process return to and maintain the desired performance[17].

Monitoring and response plans will help us during the control phase. This plan guides all staff to keep in mind the target, how frequent we have to check, the upper/lower trigger point, and the reaction plan. without this plan, we will be lost, and we may go back to our routine where is no monitor, analysis, and improvement for the process[18]

III. RESULT AND DISCUSSION

This chapter provides the significant findings of the research that shows the objective achievement. This research also verified the results of the stability of the process e by applying the Six Sigma tools and techniques (DMAIC): with the following stages: Define, Measure, Analyze, Improve, and Control. For each stage, Lean Six Sigma techniques, such as Project Charter, Data Collection Plan, Cause, and Effect Diagram. Failure mode effects analysis (FMEA), Pareto Chart, implementation plan, and Monitoring-Response-Plan

Understanding the Six Sigma method's essential features, obstacles, and shortcomings allow organizations to better support their strategic directions and increase coaching, mentoring, and training needs. It also provides opportunities to implement six sigma projects better. It integrates the lessons learned from successful six sigma projects and considers further improvements to the six sigma approach. Practical six sigma principles and practices will succeed by refining the organizational culture continuously. Cultural changes require time and commitment before they are strongly implanted into the organization.

The Process stability is one of the most important concepts of the Six Sigma methodology or any quality improvement methodology for that matter. Stability involves achieving consistent and, ultimately, higher process yields through the application of an improvement methodology.

Comparing the situation between 2019 and 2020, we can see a difference after applying six sigma tools. It improves the workflow, changing worker culture, depending on engineering tools to defined problems and finding solutions. Reducing breakdown percentage, keep the process within specification by reducing the variation.

Prioritize the Risks by Sorting the RPN from the Highest Score to Lowest Score. This helps us to determine the most critical inputs and the causes for their failure, and this rustles to the first 7 Potential Effects or Failure cover 64.85% of the Total RPN

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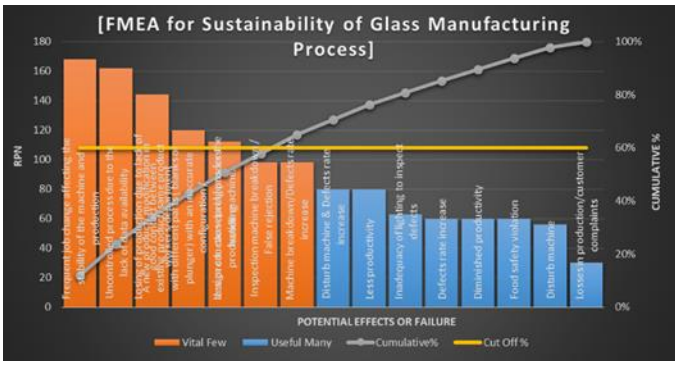

Fig.2: Pareto chart

After prioritizing our effects on the process's stability now, we can understand the cumulative impact of issues. Corrective and Preventive action can be better planned. And now Gives a focused, simple, and clear to find vital few causes. which going to helps us in problem-solving and decision-making.

Controlling the process is the most critical stage after this improvement and stability, and this is the responsibility of everyone who works in the organization. this is teamwork, especially in the glass manufacturing industry are immense with more workers and 24 hours of running the plant and has many factors that can affect the stability

Following monitoring and response plan will help keep checking, recording, and following up if any variation occurred. once these procedures, not the following company will go back as before no data to be recorded and unavailable breakdowns root causes and solutions

IV. RECOMMENDATION

In this study, we have recognized the improvement in the process in general through multifactor, and most of the recommendations mentioned in the methodology section were technical. In general, recording data, analyzing data, finding root causes, improving, and communicating, following up, and taking suggestions from operators related to machines. All help in process stability. I recommend functioning Six Sigma effectively. Six Sigma requires buy-in from everyone involved. It requires a sizable upfront cost to implement and train employees on the methodology of Six Sigma and its execution. Employees of all levels must be trained in the various positions of the methodology as well.

V. CONCLUSION

As shown in this research, improvement can be achieved by implementing FMEA, training for employees, following SOP's, and Total Productive Maintenance.

This research study has shown that Six Sigma can be implemented within the glass manufacturing industry. It has also been shown that Six Sigma can improve analysis procedures to identify variation in the process, which was helpful during the use of the DMAIC approach.

Overall, organizations can benefit significantly from implementing Six Sigma analysis tools into their organizations but determining which tool to use can be complicated. Therefore, a black belt employee will help organizations decide which Six Sigma analysis tool is best for their organization.

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REFERENCES

[1] Aboelmaged, Mohamed. (2010). Six Sigma quality: A structured review and implications for future research. International Journal of Quality & Reliability Management. 27. 268-317. 10.1108/02656711011023294.

[2] Adan Valles et. Al (2009), ―Implementation of Six Sigma in a Manufacturing Process: A case study‖, International Journal of Industrial Engineering, 16(3), pp 171-181

[3] Andersson, R., Eriksson, H. and Torstensson, H. (2006), "Similarities and differences between TQM, six sigma and lean", The TQM Magazine, Vol. 18 No. 3, pp. 282-96.

[4] Coleman, S. (2008). Six Sigma: an opportunity for statistics and for statisticians. Significance, Vol. 5, Issue 2, pp. 94-96.

[5] Edgeman, R.L. & Dugan, J.P. (2008). Six Sigma from products to pollution to people. Total Quality Management, Vol. 19, Issue 2, pp. 1-9.

[6] Erwin, J. (2000), "It's not difficult to change company culture", Supervision, Vol. 61 No. 11, pp. 6-11.

[7] E. V. Gijoa, Johny Scariab and Jiju Antonyc, (2011), ―Application of Six Sigma Methodology to Reduce Defects of a Grinding Process‖ doi: 10.1002/qre.1212 qual. Reliab. Engng. Int. 2011, 27, pp 1221—1234

[8] Dalal, A. F. (2011). The 12 Pillars of Project Excellence: A Lean Approach to Improving Project Results. CRC Press Mulrow CD. Systematic Reviews: Rationale for systematic reviews. BMJ. 1994; 309: 597–599.

https://dx.doi.org/10.22161/ijaers.711.1 *ISSN: 2349-6495(P) | 2456-1908(O)*

[9] Md. Enamul Kabir, S. M. Mahbubul Islam Boby, Mostafa Lutfi, (2013), Productivity Improvement by Using Six-Sigma‖, International Journal of Engineering and Technology Volume 3 No. 12, December, 2013, pp 1056-1084.

[10] Muralidharan, K. & Raval, Neha. (2017). Six Sigma marketing and productivity improvement. Productivity: A Quarterly Journal of the National Productivity Council. 58. 107-114.

[11] Perzyk, M. (2007). Statistical and Visualization Data Mining Tools for Foundry Production. Foundry Commission of the Polish Academy of Sciences, 7(3), 111 – 116.

[12] Ploytip Jirasukprasert et. Al (2012), ―A Case Study of Defects Reduction in a Rubber Gloves Manufacturing Process by Applying Six Sigma Principles and DMAIC problem Solving Methodology‖, Proceedings of the 2012 International Conference on Industrial Engineering and Operations Management Istanbul, Turkey, July 3 – 6, 2012, pp 472-481.

[13] Raisinghani, Mahesh & Ette, Hugh & Pierce, Roger & Cannon, Glory & Daripaly, Prathima. (2005). Six Sigma: Concepts, tools, and applications. Industrial Management and Data Systems. 105. 491-505. 10.1108/02635570510592389.

[14] Shanmugaraja, Muthuswamy & Nataraj, M. & Gunasekaran, N.. (2011). Quality and productivity improvement using Six Sigma and Taguchi methods. Int. J. of Business Excellence. 4. 544 - 572. 10.1504/IJBEX.2011.042157.

[15] S. Pimsakul, N. Somsuk, W. Junboon, and T. Laosirihongthong, (2013), Production Process Improvement Using the Six Sigma DMAIC Methodology: A Case Study of a Laser Computer Mouse Production Process‖ The 19th International Conference on Industrial Engineering and Engineering Management, DOI 10.1007/978-3-642-37270-4 13, © Springer-Verlag Berlin Heidelberg, pp133-146

[16] Subramaniam, Murugan & Noordin, Muhammad Khair. (2020). Eight Discipline Methodology in Internship Program to Improve Future Proof Talents Among Graduate Engineers.

[17] Tushar N. Desai and Dr. R. L. Shrivastava, (2008), ―Six Sigma – A New Direction to Quality and Productivity Management‖ Proceedings of the World Congress on Engineering and Computer Science 2008 WCECS 2008, October 22 - 24, 2008, San Francisco, USA

[18] Van Den Heuvel, J., Does, R. J., & Verver, J. P. (2005). Six Sigma in healthcare: lessons learned from a hospital. International Journal of Six Sigma and Competitive Advantage, 1(4), 380-388.