Six Sigma as a Strategy for Process Improvement in Industry 4.0

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Abstract

Quality improvement methodologies are important for efficiency, effectiveness, and productivity in diverse sectors. Six Sigma being a management technique has been widely utilized to improve quality in manufacturing and service systems. This research is focused at the systematic identification of opportunities for possible implementation in the manufacturing and service sector. Firstly, a deep appraisal was conducted with a focus on the introduction to six sigma and previous research on related philosophy. Secondly, the application of six sigma in service and product based system was investigated. Finally, Six Sigma was applied to solve real life problem, using data obtained from a food processing industry while recommendation was made using six sigma from the perspective of industry 4.0. This globally recognized technique requires strategic implementation for an operational and optimal outcome to achieve a reduction of cost, errors, time and quality improvement for customers' satisfaction. The systematic study serves as a bird's-eye view for strategists and professionals in the manufacturing and service industries to help boost quality, productivity, and performance in manufacturing and service based systems. Also, it is recommended that product and service-based sectors adopt the Six Sigma technique for optimal outcome in organizations with the excellent process and quality product using modern manufacturing technologies of Industry 4.0.

Keywords: Quality management, Lean Six Sigma, product sector, service-based sector, Industry 4.0.

1. Introduction

The Six Sigma philosophy was first introduced in the early 1980s as a scientific methodology in the third industrial revolution by Motorola, a study was carried out on Deming's research on quality control centred on process variation by one of the strategic managers of the company. The whole idea behind the philosophy of the six-sigma implemented by Motorola was to reduce costs of products in a system at the same time improve system performance and product quality. According to Kumi and Morrow (2006), the six-sigma method was modified to a more interesting philosophy focused on the "Define, Measure, Analyse, Improve, Control (DMAIC)" method, by an organization called General Electric, and also "Define, Measure, Analyse, Design, Verify (DMADV) or Design for Six Sigma (DFSS)", since the introduction, the methods have become very popular and applied in different systems globally, a good number of researchers have also focused on a hybrid system of lean and six-sigma. Six Sigma is of great benefit to manufacturing systems (product and service-based), especially in terms of quality improvement in systems, increasing the satisfaction of customers and reducing or eradicating defects in products (Kanigolla et al. 2013; Kwak and Anbari 2006). According to Parast (2011), six sigma has a huge transformation in terms of solution power when compared with other process improvement philosophies, the major difference is that Six Sigma offers system framework which is able to explore and facilitate solution procedure to problems all over the organisation. Day by day the philosophy continues to get popular in academics and industries. As scholars keep experimenting and observing how best to improve on existing philosophy to address the pressing need of the industry. Also, strategic staff or managers of industries try as much as possible to implement the methodology in manufacturing and service-based systems to increase productivity, quality of products so that customers' satisfaction is attained.

Raisinghani et al. (2005), assumed that the main objective of Six Sigma is to achieve a high level of quality to roughly 99.9%, the implementation of the philosophy by Motorola brought a paradigm shift in the service and product-based systems making the tool a very predominant technique used for solving problems in the industry, thereby achieving a high level of quality. Six-Sigma has been used to solve problems related to quality improvement in organizations, particularly the manufacturing sector and other product and service-based systems. Other sectors apart from industries have also used the Six-Sigma philosophy extensively (Chakrabarty et al. 2007). One interesting sector where the philosophy of Six Sigma has been used in literature is the medical and healthcare systems. This approach has changed and improved the pattern of operations in healthcare systems (Anthony et al. 2018; Ninerola et al. 2019; Arcidiacono et al. 2017). Concerned organizations, be it product or service based, are looking out for the best possible ways of improving the quality of their processes as well as the effectiveness of their manufacturing systems. This is no doubt will improve their product and service network delivery (Galdino et al. 2017). The ultimate purpose of this research is to systematically identify areas where Six-Sigma has been applied in product and service-based systems both in developing and developed nations. The area focused on including Manufacturing organizations, the health care sector, SME/retail outlet/fast-moving consumer goods, transport systems, banking sector and education sector. Recommendation for future research with opportunities and prospects for the new revolution.

2. Six Sigma Approach in Product and Service Based Sectors

Approaches to business improvement using statistical approaches have evolved and grown throughout time, and today firms like GE, Honeywell, Motorola, DuPont, American Express, Ford, and others are utilizing the process-focused, statistically-based Six-Sigma methodology to enhance corporate performance (Snee 2004). More integrated improvement has also been observed when six-sigma is combined or integrated with big data (Laux et al. 2017). Antony et al. (2007) opined that the six-sigma project in any sector would require team tools, process tools and statistical tools to be effective. Six Sigma defines two types of projects: DMAIC projects for improving existing products, services, and business processes, and DFSS projects for creating new value, which takes a more radical approach (Aziz and Osada 2010).

3. Six Sigma in Service Based Systems

A service system is a set of technological and organizational networks which work together to provide services that meet consumers' requirements, specifications, and aspirations. In the service fields involving management, operations, marketing, engineering, and design, the phrase "service system" is employed. The health-care industry, supermarket retailing, banking, and education are all discussed in this article.

3.1. Six Sigma Application in Healthcare System

The goal of healthcare systems is to offer services that are required to address the everyday health needs of a certain community. Antony (2018) demonstrated the Six Sigma methodology's systematic influence in increasing healthcare quality. The findings point to an increasing interest in Six Sigma adoption research in the healthcare sector. In a tertiary care hospital, George et al (2018) investigated the impact of Six Sigma methodology on minimizing prescription errors. The use of the DMAIC methodology resulted in a significant reduction in medication mistakes. As a result, the six sigma value improved dramatically. Regular audits and thorough follow-up can help to ensure that the medication use process continues to improve significantly. Six Sigma is a beneficial idea for improving healthcare procedures, according to research conducted by Lifvergren et al. (2010). When compared to the performance of comparable healthcare reform programs, a success rate of 75% is impressive. This supports the idea that Six Sigma should be included in healthcare development activities as part of the improvement practices.

The outcomes of the application of Six Sigma at the Red Cross Hospital in Beverwijk, the Netherlands, were addressed by Heuvel et al., (2005), in a research conducted, they found that the completed projects saved €1.2 million per year. All active projects are estimated to save €3 million in net annual savings. According to Bandyopadhyay and Coppens (2005), as industry factors become more prevalent and competitive, many U.S. hospitals are becoming increasingly aware of the critical need to control operating costs in order to meet and exceed patient care quality expectations. In health care quality management for hospitals, the Six Sigma approach was implemented. A healthcare business can enhance patient outcomes by understanding, satisfying, and exceeding their needs and expectations, while remaining competitive by decreasing costs and enhancing quality. Six Sigma might be used to improve the triage process in emergency departments and reduce the amount of time patients spend there, according to the author. Laboratory methods can also be investigated to see if there are any redundant processes that can be eliminated while still achieving the required results. The DFSS Six Sigma methodology is implemented when considering design which has to do with new systems and facilities, it can also be utilized for renovation of existing healthcare facility. Patients' behavior is considered while developing and laying out operating rooms, laboratories, and waiting rooms, with factors such as patient, doctor, and visitor convenience being put into consideration. In an optimization process by Rohini and Mallikarjun (2011), the operating room of a corporate multi-specialty hospital in Bangalore was considered and the DMAIC Six Sigma method was recommended. The DMAIC technique demonstrated a broader application, demonstrating how a healthcare company may become efficient in decision-making, problem-solving capabilities and gain competitive advantages in a commercial setting.

3.2 Application of Six Sigma in SME/Retail Outlet/Fast Moving Consumer Goods

Deshmukh and Chavan (2012) noted that due to increase in global economic activities and competition systems, small and medium-sized enterprises (SMEs) products and services should be of best quality. Thus, the SMEs need to develop a more predictive system to ensure reliability in the supply of products and service in the supply chain. Robust quality management processes need to be in place in SMEs to be predictable and reliable to remain a strong link in the supply chain. Hence, the Six Sigma approach should be pragmatically utilized, in terms of quality improvement and sustainable development of the SMEs sectors in large and small enterprises. Sharma and Sharma (2014) discussed that global competition forces commitment from SMEs to quality management practices by ensuring their production processes are reliable to meet customers' and business' requirements. In this study, six sigma tools such as "pareto analysis, fish-bone diagrams, histograms, FMEA, box plots, control charts and process capability plots for analysis" were utilized to provide improved level of performance in machines and plant as validation for improvement. Kaushik et al. (2012) applied six sigma methodologies in a SMEs producing bicycle chains, here, the six sigma level was improved from 1.40 to 5.46 through implementing solution ideas to achieve accuracy of cycle chain bush. Savings in cost avoidance because of achieved decreased products rejection, smaller and medium sized firms has been adopting the systematic approach of Six Sigma due to its operational and business benefits. Antony et al (2005) took a survey of SMEs with focus on the lean six sigma methodology utilized; 69 percent utilized the DMAIC approach for continuous improvement, while 19 percent utilized the DFSS, 6 percent used lean six sigma and 6 percent employed both DMAIC and DFSS methodologies. Snee (2004) researched on Six Sigma application for business improvement methodology. The review is a demonstration of the effectiveness of six sigma in SMEs and retail outlets.

3.3. Application of Six Sigma Technique in the Banking Sector

Six Sigma is a business initiative and not only a mere quality initiative, but it has also been effectively utilized in financial institutions leading to cost avoidance and revenue growth (Uprety 2009). The competition in India banking sector has experienced improvement due to customers' requirements with specifications to match the international standard obtainable in other countries. For banks to remain competitive in challenging requirements by customers, a robust systematic approach like the Six Sigma methodology is now being adopted by financial services providers to enable better operational efficiency, improved customer service and cost savings (Uprety 2009). Banks can use the Six Sigma methodology to identify limitations and proffer optimized solutions to satisfy the customer's requirements and business or process requirements. Establishing a process to meet all customers' requirements especially when customers are both internal and external can be challenging, however, a team of cross-functional units can help refocus customers' specification to fit the process capabilities. A study carried out by Islam (2016) in a leading commercial bank to implement Six Sigma approach in a credit card department; results from this study confirm that the quality of the credit card account opening process improved to meet customer requirements. Wang and Hussain (2011) are of the opinion that customers in the banking sector are requesting for better quality, and this challenges the process capability of the banks which requires them to improve their processes to meet the demand for new qualitative products and services.

Implementing Six Sigma have presented several benefits to the banking system, these include service charges reduction by ensuring accuracy in distribution of cash in daily reports through an effective information system, defects minimization in loans processing, defect reduction in cheque collections and payments, and inefficiencies decrease in routine operations. A study made in China's banks suggested that certain factors are instrumental to increasing the chances of Six Sigma achieving its intended goals which are: avoiding short-centered approach, excessive concentration on costs reduction, and a continuously learned process. The DMAIC project been led by a team of subject experts can produce better results in banking industry. Tang and Xiaobing (2010) implemented six sigma projects due to complaint of customer long waiting time, as they are unsatisfied with the counter service in banks. After analysis of As-Is waiting time at the counter, a queuing system optimization program was developed that effectively reduced the queuing time at the banks. Factors response for long queuing time were obtained through survey and effective analysis was performed. It is therefore an observable fact to know that reduction in the waiting time is the pain area from the voice of the customer (VOC), therefore, improving their processes to ensure the complaint is eliminated or reduced became imperative. The banks in Syrian have equally improved their performances by adopting the six sigma methodologies (Qutait 2018). The result of the study shows the importance of Six Sigma implementation in local sections of industrial and service organizations, and an observable trend in Syrian banking system continuously adopt continuous improvement methodologies like the Six Sigma. Six Sigma method is in no doubt particularly useful in the banking sector.

3.4. Application of Six-Sigma in the Education Sector

Education subdivision is an important sector designed to foster quality and all-time learning activities for masses. Cudney et al. (2020) conducted a review to in higher education system to evaluate the opportunities for successfully implementation of Six Sigma. The review suggested that the data-driven improvement methodology can be utilized in education process like teaching styles, processes in administration, and other sections of the institution. The adoption of the Six Sigma methodology in the education system will bring about efficiencies in processes within the system by ensuring the quality of learning experience is improved and the culture for continuous improvement is embraced. It was also highlighted that for thorough understanding of the applications, benefits, and challenges requires extensive research. Some reported the challenges of implementing Six Sigma methodology is the failure of institutions in properly identifying and defining its customers, lack of awareness of the improvement methodologies, lack of interest and commitment from the stakeholders, unable to cope with changes in the process, and difficulty in understanding and adapting the six-sigma methodology within the educational context. The study suggested that involving internal and external customers, having a team of subject experts and a trained six sigma personnel for six sigma projects, increasing stakeholders' involvement and commitment, and conducting toll gate reviews during the lifetime of the project can improve the number of successfully implemented Six Sigma projects in higher education.

Babajide and Moore (2015) conducted research on six-sigma project to improve the quality of engineering graduates to meet the requirements of industries by graduates having the academic deft in a preferred discipline and to utilize the skills necessary in the field. The Six Sigma DFSS methodology was applied since it is helpful in preparing and developing graduates for the workplace. This study concluded that the DFSS approach can enhance students' skill in presenting and systematically organizing ideas. Davis and Fifolt (2017) explored employees' perception of Six Sigma as a tool for facilitating changes; findings from this study conducted in one of the public higher education institutions shows that the use of the methodology to initiate and sustain change in higher education was successful. Employees' opinion about the interpersonal skills acquired been team members for the six sigma projects were reported, though they highlighted that the highly structured and statistical methods associated with it could be frustrating. Furthermore, team members found the data-driven approach of Six Sigma methodology to identify and define issues and develop standard solutions. However, the employees selected only those tools that best meet their need in the assigned projects. Yu and Ueng (2012) studied how a feedback system to monitor and reflect the outcomes of teaching can be evaluated in higher education systems using the six-sigma methodology. Some useful tools to illustrate how evaluations of teaching can be made simple and possible strategies for corrective actions were proposed in the study. Kuwaiti and Subbarayalu (2015) captured work students' attitude through the Students Experience Survey (SES) questionnaire, and analysis were done on obtained data using the Poisson distribution model. The sigma score for each learning and teaching process was evaluated, and a six-point quality rating system was initiated for each corresponding sigma score. Through this rating scale, the stakeholders in the education sector can monitor the improvement of quality parameters in the educational system and observe what teaching methods and learning styles need to be improved to attain desired the six sigma level.

Cudney and Kanigolla (2014) focused on research to evaluate the impact of undergoing a practical project on students' knowledge in Six Sigma and DFSS graduate-level courses. Six Sigma and DFSS education need practical application of theoretical knowledge. Both the Six Sigma and DFSS courses required that the student team are engaged in collaborative hands-on projects over a 16-week semester. After project completion, student surveys conducted and analyzed shows that the use of the practical project positively impacted the students' knowledge in learning course concepts. Utecht and Jenicke (2009) presented a case undertaken in an institution of higher education using the six sigma methodology to improve the salary determination process for Office Professional (OP) employees, the improvement goal of 65% was achieved after an initial goal to improve consistency by 50%. Thakkar et al. (2006) explored the benefits of implementing Six Sigma methodology for a case of educational services and its corresponding challenges; the barriers or challenges implementing Six Sigma in the education system was prioritized using Analytic Hierarchy Process (AHP). Ho et al. (2006) presented the feasibility of Six Sigma framework implementation in higher education, discussed were the integration of DMAIC methodology and statistical quality engineering education into existing curriculum, some fundamental issues in designing an effective Six Sigma training programme, and the potential applications of six sigma for educational excellence. Cudney et al. (2014) shared current best practices and trends for Six Sigma integration in higher education systems. Mehrabi (2012) worked on the evolutionary review of the benefits and challenges of six sigma projects and highlighted the key and influential elements of successfully implemented six sigma projects. Six Sigma is rapidly becoming a major driving force for technology and project-based organizations. The success of six sigma projects can be influenced by project management and control skills, management involvement and organizational commitment, cultural change and continuous training. In the study carried out by Paramasivama and Muthusamy (2012), they were able to establish a relationship between six sigma methodology and the scope of study required for undergraduate engineering program in an academic environment, to ensure the educational system is capable of producing innovative and talented graduates.

4. Six Sigma in Manufacturing/Product Based Systems

Six sigma is useful in the manufacturing sector for reducing the cost of products in a system at the same time improving system performance and product quality. McAdam and Evans (2004) conducted a study on Mancase, the world's largest manufacturer of disc drives, magnetic discs and read-write heads, storage area network (SAN) solutions and a leading developer of Business Intelligence Software. The company identified the need for an improved quality management system. Six-sigma was deployed to redesign their products and improve the supply chain. In another study by Shojaie and Kahedi (2018) a framework was developed to evaluate the quality of oil filter in automotive industry, using the DFSS method. Customer needs were identified, and failure causes of a filter were prioritized using six sigma tools such as the cause and effect diagram. The most important failure causes for action improve practices to achieve the appropriate sigma level. Also, Wei et al. (2010) studied Amway Taiwan company customers need was analyzed using six sigma techniques to tweak production to improve the replenishment process. As a result, there was less wastage of products that did not meet client needs. In India, Gijo and Sarkar (2013) used Six Sigma for the development of wind farm roadways. It improved the quality of such roads, which meant that continual repair work for damaged work was avoided, costs were cut, and resources were conserved. Kumar et al. (2013) looked at the casting sector, where Six Sigma reduced defects due to improved operations, reducing waste of important materials. Gijo et al. (2014) observed the foundry industry, and the six sigma philosophy was applied. A significant reduction was attained with cost savings of 8000USD per annum. Jirasukprasert et al. (2014) demonstrated the empirical application of Six Sigma and DMAIC to reduce product defects within a rubber gloves manufacturing organization. The root cause of defects was investigated and solutions were provided to reduce the defects. Gijo and Scaria (2010) discussed the implementation of the Six Sigma methodology in reducing rejection and rework in a honing process in an automobile part manufacturing company. Rawendra and Puspita (2020) used six sigma methods to identify the defects in milk industry packaging lines, the potential reasons for the defects were analyzed by using six sigma tools after which solutions were proffered to reduce the defects. Antony et al. (2012) discussed how Six Sigma methodology was successfully implemented in high precision and critical process in the manufacture of automotive products, resulting in a reduction of tolerance-related problems and a significant increase in first-pass yield from 85 percent to 99.4 percent. The application of the Six Sigma methodology had a considerable financial influence on the profitability of product passed systems, according to the findings.

Case Study - Manufacturing Settings

4.1 Implementation of Six Sigma in a Food Manufacturing Company to Reduce Planned Downtime

The six sigma DMAIC methodology was implemented to reduce the planned downtime in the packaging section of a food manufacturing company. The planned downtime consists of planned activities before and after production. These activities were classified as process startup and shift-changeover activities; process startup are activities carried out before the start of production and shift-changeover activities are those activities carried out after production to ensure a smooth handover to the next shift. The reduction of planned downtime in this section of the manufacturing operation became critical because the entire production process is halted when products are not packaged as planned, creating downtime for other sections of the operation. The define phase was carried out to choose a team for the project, create a project charter and to get all stakeholders to buy-in. In the measure phase, the baseline was selected and measurement system for the process validated. A brainstorming session was held with the team to highlight some probable factors for the high planned downtime and statistical tools were used to validate the critical of these factors. In the improve phase, one of the activities carried out was using Single Minute Exchange of Die (SMED) to re-evaluate the activities carried out during the planned downtime, activities previously done internally were moved to external activities as shown in Table 1. Table 2 presents the time reduction achieved for these activities by improvement ideas suggested by the team members.

Table 1. Conversion of Internal to External Activities

STAGE	ACTIVITY STEP	AS-IS		AFTER	
		INT	EXT	INT	EXT
Process Startup	Cleaning of Machines Parts	X			X
	Setting of Printing Device	X		X	
	Setting of Machine Parameters	X		X	
	Receipt of products from Accumulator/ Process	X		X	
Shift Changeover	Machine Stop for Shift Closing	X		X	
	Collection of Products from Process	X			X
	Collection of Accumulation Weight	X		X	
	Machine parameters collection for General Report	X		X	
	Wrapper measurement for wrapper variance	X		X	
	Completion of Production Reports	X			X

Table 2. Reduction of Internal Activities Time

STAGE	ACTIVITY STEP	AS-IS	AFTER
		INT	INT
Process Startup	Setting of Printing Device	2mins	30sec
	Setting of Machine Parameters	1min	30sec
	Receipt of products from Accumulator/ Process	3mins	1min
Shift Changeover	Machine Stop for Shift Closing	1min	30sec
	Collection of Accumulation Weight	1min	1min
	Machine parameters collection for General Report	1min	30secs
	Wrapper measurement for wrapper variance	4mins	1mins
Total time used/saved for planned downtime Activities		**13m**	**5m**

Figure 1 shows the control charts designed to monitor if the project was in control, and the planned downtime trend in Figure 2 shows baseline of 2.81% taken in September 2020 and the improved performance from October to December.

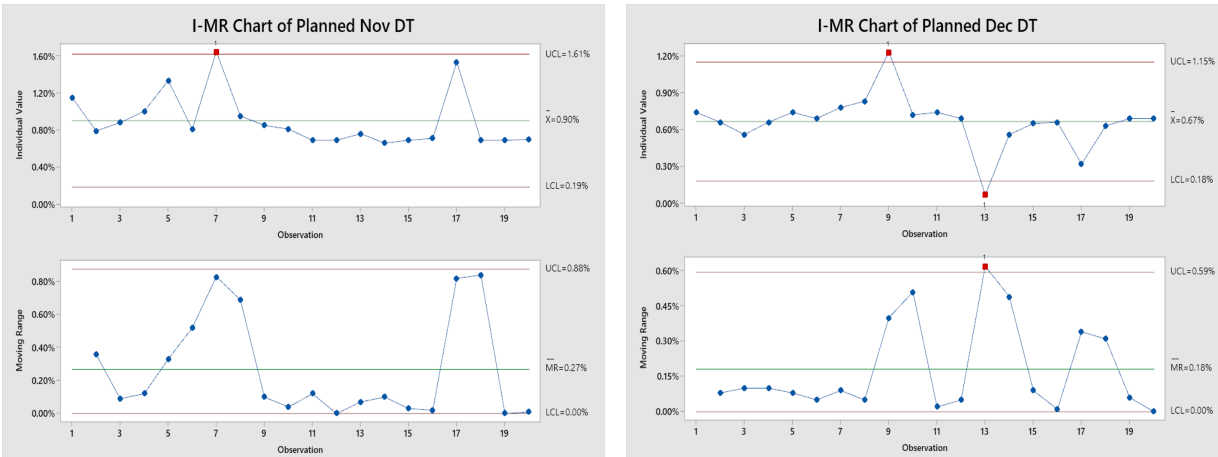

Figure 1. Control Chats for Planned Downtime Project

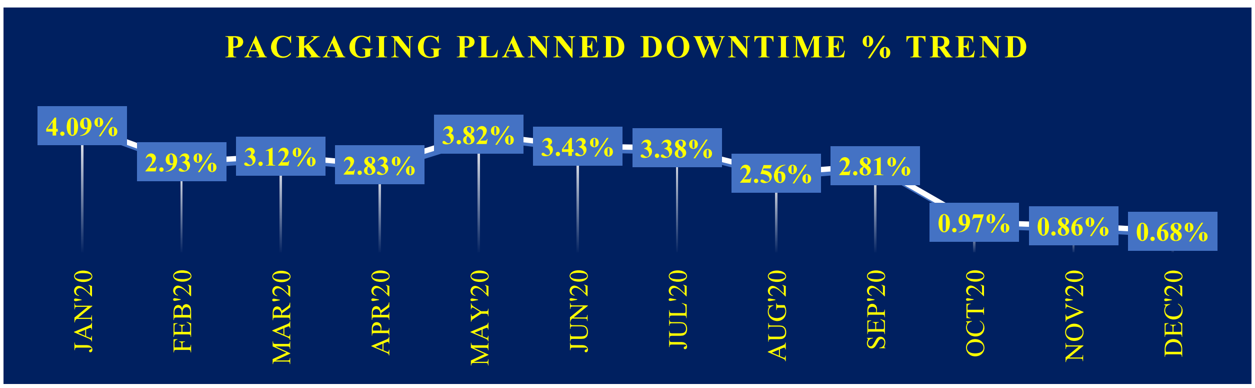

Figure 2. Performance Trend for Planned Downtime Project

4.2 Application of Six Sigma in the Packaging Section of a Food Processing Industry to Reduce Production Downtime

Another case study where Six Sigma was implemented in a manufacturing industry was to reduce the downtime in the packaging section of a food processing industry. Figure 3 represent the Fishbone diagram designed to evaluate the potential factors responsible for the high downtime experienced in the packaging section of the process. One of the critical factors discovered in the course of the project was the high response time for support team. A good instance is the response of engineering department to machine breakdown, a cycle time study was carried out to show percentage contribution of the fixing time, response time and operators' time as shown in the Pareto Chart in Figure 4. The fixing time which is the actual time taken by the engineering team to fix the machines contributed 55%; the response time which is the time the engineering team was informed, and the time spent by them to get all necessary equipment and parts to the machine contributed 25%; and operator time which is the time spent by the operator to resolve the problem before engaging the engineering team if not successful contributed 19%.

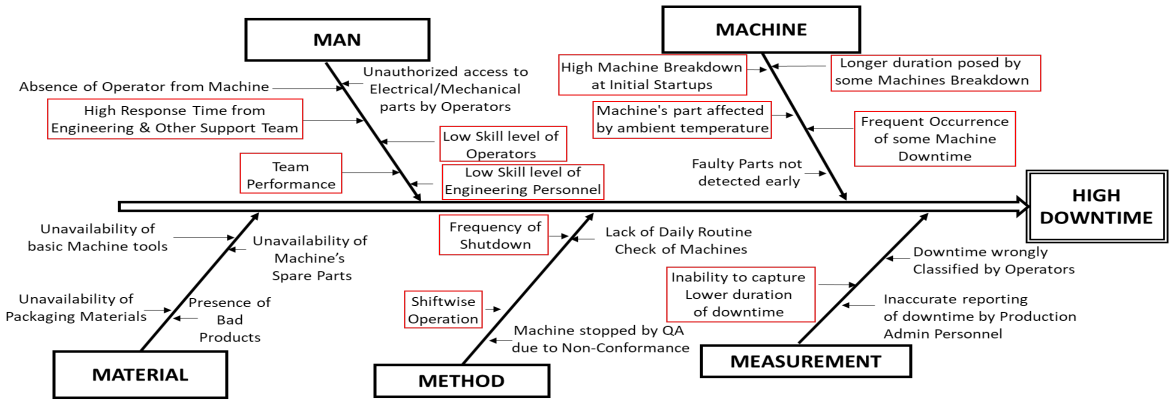

Figure 3. Fishbone Diagram for Downtime Reduction Project

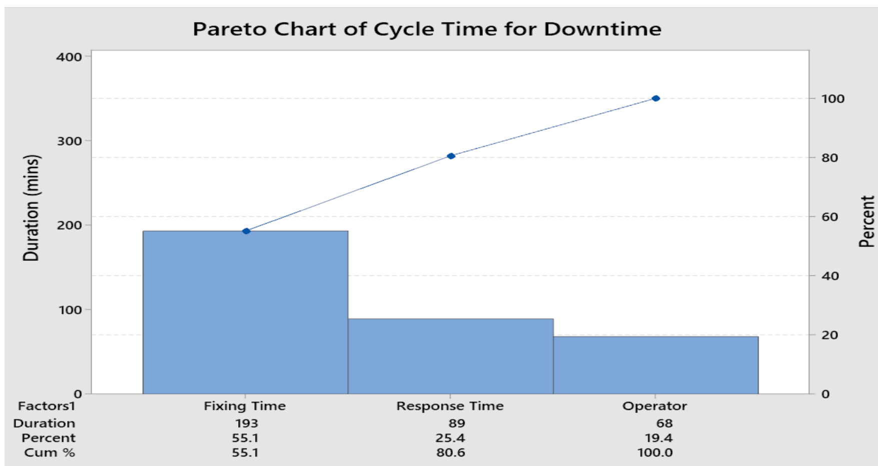

Figure 4. Pareto Chart of Cycle Time Study for Downtime Reduction Project

Validated critical factors in the project is presented in Table 3, some six sigma statistical tools used were Two-Sample T-Test, Paired T-Test and Mann-Whitney Test. Validated factors were evaluated by the project team members for improvement ideas. After implementation of improvement ideas, 45% reduction was achieved from the baseline of 12.14% in September 2020 to the end of the improve phase in April 2021 with performance of 6.65%.

Table 3. Validated Critical Factors for Downtime Reduction Project

S/N	PROPOSED CRITICAL FACTORS	TEST	RESULT
1	High Response Time by Engineering Team	Brainstorming; Pareto Chart	Critical
2	Team Performance	Two-Sample T-Test	Not Critical
3	Skill Level of Operator and Engineering Personnel	Brainstorming; Pareto Chart	Critical
4	Machine Parts Affected by Ambient Temperature	Time Series Plot; Paired T-Test	Not Critical
5	High Impact Downtime Factors	Pareto chart (Duration and Frequency)	Critical
6	Frequency of Fresh Startups	Two-Sample T-Test	Not Critical
7	High Downtime at Fresh Startups	Brainstorming; Time Series Plot	Critical
8	Shift-wise Operation	Two-Sample T-Test	Not Critical
9	Short Stoppages during Operation	Box Plot; Mann-Whitney Test	Not Critical

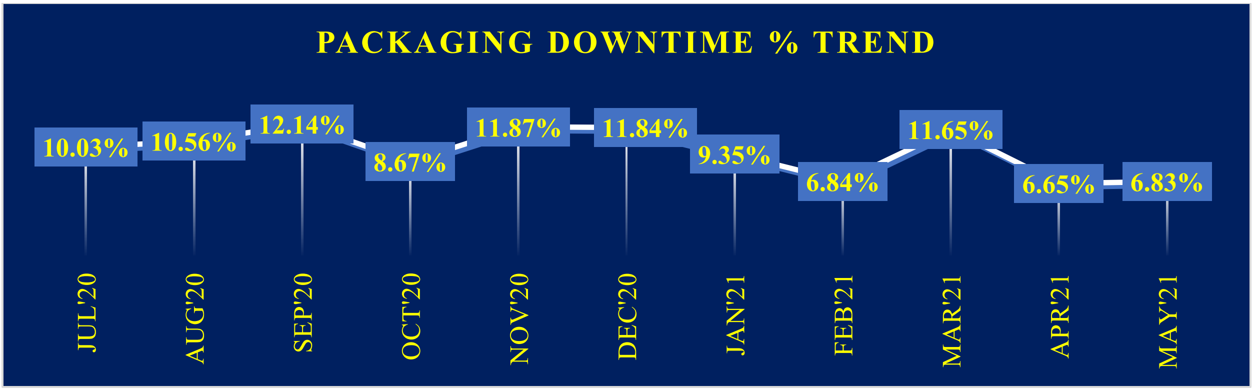

Figure 5. Performance Trend for Downtime Reduction Project

5. Six Sigma and Industry 4.0

Having discussed in detail the applications of six sigma in product and service systems, it is equally imperative to be aware of the importance of six sigma in the era of the Fourth industrial revolution. Industry 4.0 is the transformation of systems, adopting or implementing smarter manufacturing process with the help of perceptive and ground-breaking technologies and cutting-edge information systems like artificial intelligence and machine learning, interconnection of robots and the Internet of Things. For factory systems to work effectively, continuous process improvement methods, especially the Six Sigma philosophy is advantageous. The data-driven procedures often used by the prevalent process improvements are strengthened by advanced Industry 4.0 expertise. Process improvement philosophy could help organizations in driving state-of-the-art technologies especially in this era of industry 4.0, where there is high tendency of obtaining massive dataset timely with conceivable analysis, faster and accurate results. Considering a manufacturing setting, such reliable and limitless data can be obtained effortlessly from suppliers and customers cross point using intelligent systems, this will greatly improve six sigma practices by putting operations on the right track leading to the massive and profitable growth of the organizations. The tools and techniques in Six Sigma can eliminate defects and errors within a process, reducing variation and offers a platform for continuous improvement. Six Sigma philosophy and methodology can help facilitate Industry 4.0 processes. Employing cutting-edge or innovative technology to improve a process will eventually lead to a process that can considerably be improved upon by implementing the process improvement.

6. Conclusion

Six Sigma has been widely used in diverse area of operations especially in the product and service-based sector. This study focused on the analysis of six sigma in product and service-based systems as a systematic improvement methodology. From this periodical study, there is a clear observation that the philosophy has been used intensively in the health and manufacturing sector. It was equally observed that six sigma is common in developed countries while developing nations still struggle to embrace the philosophy. The classical and unproductive methods often used at workplace (product or service-based) have necessitated constant and continuous service delay and production losses. As a result of the shortcomings often experienced while considering veracities and trepidations in production, it is important to focus on excellence, quality, and superiority in terms of product developed or services rendered. This is possible by implementing six sigma methodology. If effectively applied, there is a tendency to increase production efficiency and accomplish set goals in industrial and service systems, instead of poor defective products, standard products are achievable. Finally, the goal of maintaining the overall satisfaction of customers' is possible in manufacturing companies and service-based systems, especially where customers are considered important stakeholders in every stage of the business process. There is no doubt that implementation of six sigma with technologies of Industry 4.0, will bring about timely production of high-quality products at a reasonable price, thereby ensuring quality as a critical aspect of the product- and service-based system.

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