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Analysing the effectiveness of Lean Six-Sigma Approach on Reduction of MUDAS (Wastes). A case study at SME (Small Manufacturing Enterprise) of Pakistan

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ABSTRACT: The lean six-sigma approach consists of DMAIC concept, clogged with variety of tools which starts from underlying cause identification, improving, controlling & finally giving the way to make process consistent through different sort of suggestions & improvements, the approach is more result-oriented when the lean apparently work with preceding steps. Lean deals with eight wastes of targeted place i.e. motion, waiting, over-processing, over-production, defect, inventory & transportation. The lean six-sigma concurrently can be put into practice to reduce the MUDA (wastages) of the enterprise particularly for small manufacturing enterprises (SMEs). The existing SMEs are lacking in different approaches and following no any kind of meticulous method which could be counted in latest techniques & catered the shortcomings of processes. The large corporate sectors are moving over the footprints of lean six-sigma approach which is contented with DMAIC & DMADV, similarly, the other quality tools i.e. Fish bone diagram, regression analysis, correlation analysis etc. Specifically, in developing countries, SMEs are being operated in less budget, so, to increase the profit margin, the MUDAs are to be mitigated. In this research, the two MUDAs are selected of small manufacturing enterprise i.e. Defect & motion. They are catered through lean six-sigma approach to validate the effectiveness of approach. Right now, the yield loss is 8% owing to major fault i.e. Paint fault, and average time among the stations to complete a job is 28 sec because of tumult & placement of machines at haphazard positions. Both MUDAs have been soothed/passed through Lean six-sigma approach to ascertain the effectiveness & take the peerless results.

Keywords: SMEs; LEAN; SIX-SIGMA; DMAIC; DMADV; MUDA.

Abbreviations: SMEs, Small manufacturing enterprises. DMAIC, Define, measure, analyze, improve & control. DMADV, Define, Measure, Analyze, Design, and Verify.

I. INTRODUCTION

Six-sigma is data guided problem-solving approach which can use to mitigate errors of any system. The whole approach is based upon the satisfaction of customer and supplier under some agreed process limitations, the approach goes on doing the continuous refinement. The approach revolves around one key factor which is the performance of the process which are supposed to be 99.99996%. The Six sigma is the course which consists or starts from identification, segregation & pertinency for error improvement

Central Tendency of Six Sigma consists on

- The central point of six sigma is indispensable thought
- CTQ–Features which are important to patron
- Flaws–Unsuccessful to achieve the customer requirements.
- Process Potential–Process efficiency to produce at the patron requirement.
- Deviations–Difference of process capability and process actual.
- Stability –Assurance for process to meet the required level of customer.

Development – Considering the process for designing to meet the requirement of customer. Six-sigma is equipped with DMAIC approach i.e. Define, Measure, Analyze, Improve, & Control. These sophisticated steps help to settle down intricate problems. Each step has different traits which begins with Process mapping, boundaries of the process, SIPOC, swim flow diagram, CTQ and project charter which includes the Ishikawa diagram, cause and effect matrix, pare to charts with analysis, Data gathering procedure, graphical representation, process potential. Moreover, the analyzing phase includes correlation, hypothesis testing, residual and linear regression. Betterment phase starts from multi regression & ends at design of the experiment. Assurance or control phase of six-sigma has FMEA, POKA-YOKE, SPC (Statistical process control) charts and ending of the phase is done through control plans and standardized operations for producer. Such tools with advanced techniques are used to get rid of complicated problems and cure the process

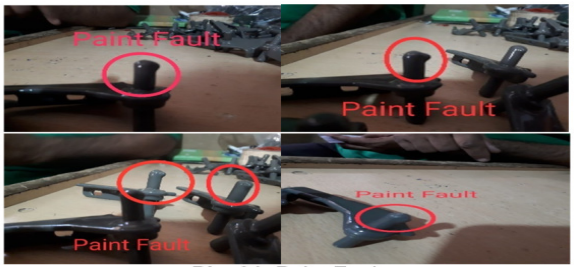
II. RESEARCH GAP

The small and medium size industries must manage the sustainable practices for business growth [11]. The small medium-sized enterprise monitoring their daily production on paper which is far away of new manufacturing execution system (MES), to meet the nowadays demand and cater the technological difference, researchers recommended RFID (radio frequency identification) real time manufacturing system which is surely to be replaced in upcoming days, this

method is more efficient & reliable source of data gathering, product quality and reduced paper wastage, further, nowadays benefits of lean six can also be seen in medical technology [4]. The researchers recommended the five function of NFC's which will have to be linked with android system (Interface) to take real time data [24]. SME required to get their own model of SM (Industry 4.0) with concept and agenda [22]. The micro, small and mean type of industries require focused intitivae through governments' flexible policies and laws, so, it is important to set doctrines for them in order to reinforce the drive [28]. The lean Six is not only dealing with tangible problems, it can also be applied on intangible results to understand the relation of facilitators at manufacturing organizations [29]. Many a practitioner have verified the authenticity of lean six sigma models that have been suggested by modern researchers [30]. The small and medium size enterprises specially of subcontinent are facing several challenges which are to be challenged [8]. Having read the aforementioned references of different researchers and lean six sigma practitioners, it is concluded that all the researches are applied to figue out the challenges of various industries. This resarch is particular case study of lean six sigma which is being applied to SME, further, it made SME help to get rid off the most repetitive or noisy defect which was being complained repetitivetly from its supplier, the relation of first MUDA is also calculated computationally through equation. The another MUDA is internal which is related to plant haphazad layout owing to unplanned placement of machines at random locations. These both MUDAs are mitigated through lean six sigma approach for the survival and stability of SME, because the apporach is being adopted worldwide owing to consumer-oritenation relationship for companies accomplishment [6]. The second MUDA is depend upon the investment but complete study has been sharedby comapring before and after timings as metioned in conclusion section.

III. INTRODUCTION OF SMALL MANUFACTURING ENTERPRISE

The concept of the lean six sigma cannot be implemented without auspices of leadership of small manufacturing enterprise or any other kind of other industries [1], so, the ownership of managegent is very crticial for the plancement of Lean six sigma methodology. At times minor changes in current practices can make major impact on the reduction of shortcomings [2]. Small and medium enterprises have to compete and participate in the race productivity and quality for their survival [13]. Let's have a look on the small manufacturing enterprise where the research is to be done. The SME was established in 1996 with name ASAD ENGINEERING WORKS. The motive behind the business is to manufacture the different manufacturing parts/sub-assemblies for different home appliance industries of Pakistan. This small sector manufacturing industry has been running the business since last 23 years, it is located at Hyderabad city of Pakistan, it is being operated with about 100 employees, mainly, the industry is providing the parts to indigenous leading home appliance company of the Pakistan, the indigenous company is manufactured refrigerator and chest freezer at their plant. The ASAD ENGINEERING WORKS (AEW) is manufactured the doors' hinges and related parts. The customer company check the manufactured parts through MILL 105E standard and draw the lots accordingly. The main fault which has been challenged for ASAD ENGINEERING WORKS and to be solved immediately is Paint fault (First MUDA) in manufactured assemblies. The picture of the paint fault has been given below



Pic.1. Paint Fault.

The paint fault consisted of three main causes

- Rust Problem
- Color peel off
- Over coated layer

& the second MUDA is total motion time which is required to complete a job at plant building.

Planned Benefits. Through the introduction of six sigma approach many a breakthrough can be taken as a benefit [3]. But the planned benefit of the research is reduced the MUDAs (wastages) of a small manufacturing enterprise and use the optimal resources to boost the profit of the small manufacturing enterprise, so, took two important MUDAs which are listed below.

Research aim. On the contrary of large-scale industries, SMEs are still far away of technological & engineering approaches, especially regarding the MUDA (Waste) reduction. Therefore, mainly, MUDA will be considered and try to remove or mitigate them through lean & six sigma tools to effective utilization of resources and meet the business goals.

- Identify the MUDAS of SME.
- Use lean six sigma approach for reducing the non-value-added activities.
- Analyze the performance of lean six sigma tools on performance
- Prepare recommendations for SME

IV. FIRST MUDA (PAINT FAULT)

The six-sigma successful completion is directly linked with project performance [7]. So, for this, the goal of this article is very clear which is to identify and understand the relationship between critical success factors for Six Sigma programs and its projects performance. The lean six sigma methodology is applied to overcome the tautology of defects [10]. So, improvement research which is to be done in for Paint fault is gone through the mention steps

- Data collection
- Software/tools
- Data analysis

Data collection. The Six sigma pave the path to collect the data and prove it by giving numerous results in real short time [19]. The Small manufacturing enterprises are not much developed and doesn't follow any kind of system to get the data, so, the data would be gathered

through two ways, firstly, through data sheet which is designed by researcher and would keep on collecting and the secondly, the data would be collected from customer which is getting effected.

Software/tools. The Minitab software would be used for data processing, this software is specifically designed for researchers & six-sigma professionals. The Software is containing all the tools of lean six-sigma and follow the way of DMAIC, the raw data of the arduous problems can easily be converted into meaning results. The software is enclosed the following tools of DMAIC/DMADV

- Project charter
- Voice of the customer
- Affinity diagram
- Kano model
- CTQ
- Process Map
- Data collection
- Process capability
- Measurement system analysis
- Yield (RTY)
- Multivariate analysis
- Fish-bone diagram
- FMEA
- Hypothesis testing
- ANOVA
- Scatter plot
- DOE
- DOE
- Fully crossed design
- Partially crossed design
- Response surface
- EVOP
- SPC
- Control Plans
- SOP
- Measurement system analysis (MSA)

All the steps have been mentioned above because after completion of research, there could be some amendments or new practices which are to be changed or amended through standard operating procedures (SOP) [9].

Data Analysis. The data analysis is the most important or vital step of the research, through this step the data is cultivated and lastly the desired results achieved through the potential causes, in precise words, the processes' excellence can be achieved by applying lean six-sigma [16]. For this, the first move of the data analysis is done through the Define, in which the product stream is identified and moreover the project scope is limited having seen the flow of the product. When the scope of the project has been defined then the SIPOC is created, through this diagram, the supplier, starts and ends points of the processes, troubles, delivery of the products to the customers & necessities required for product are defined. Secondly, the Voice of the customers is made which is also called the CTQ (Critical to Quality) tree in which the problem is emphasized. The CTQ tree is made having taken the considerations of floor staff which includes operators, technician, supervisors, inspectors etc. The third step of data analysis is measurement phase. In this step, all the information is gathered to understand processes information, processes efficiencies, processes paths or activities. The measurement phase follows the below track figure

Table 1: Way forward.

First	Potential cause classification
Second	Precedence of the Potential causes
Third	Data collection schedule
Fourth	Existing Sigma level with yield rate
Fifth	MSA (Measurement system analysis)

The detection of potential causes is done through Ishikawa diagram which are earlier detected through SIPOC and particularly by VOC/CTQ analysis. All the CTQ are drawn out by Ishikawa or cause-and-effect diagram through segregation of Man, Machine, Material, Method, Environment which are shown in below figure.

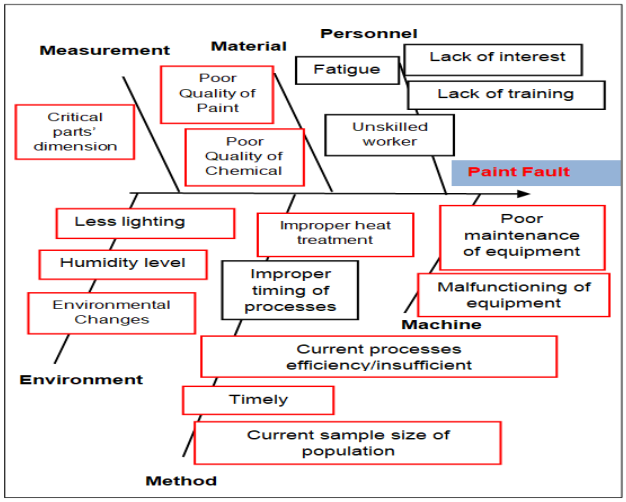


Fig. 1. Ishikawa diagram.

The lean six sigma change methodology according to customer requirements to consider as paramount [18]. All the possible causes are drawn on the wings of Ishikawa diagram to cover all the effects of the paint fault in hinges i.e. Main effected product of the small manufacturing enterprise. The effects are gathered

through the previous data history of this fault. Later, the effects are analyzed through Pareto analysis i.e. tool of Minitab

Pareto's Principle results. Pareto's principle is operated on the logic 80:20, so, the effects' values have been mentioned in below tab

Table 2: Pareto chart.

S. No.	Potential	Score
1.	Current Processes insufficient efficiency	279
2.	Environmental Changes	279
3.	Humidity level	279
4.	Improper method (Excessive paint)	279
5.	Paint Layer (60-120, +30 microns)	209
6.	Critical parts' dimensions	209
7..	Complicated part design	209
8.	Poor Inspection Sampling plan	192

Existing processes' strength. The 6 σ gives quick & innovative solution to any problem [12]. That is why existing process capability of small manufacturing enterprise has been identified in terms of sigma level & yield % with defects per million opportunities, moreover, having measured the existing sigma level with yield % and defects per million opportunities, the target is also marked for the same parameters in the below table

Table 3: Existing situation.

Study	Yield %	Defects per Million opportunities	Sigma level
Existing Strength of the process	90.39 %	96031	2.8

Correlation Analysis. The lean six sigma approach is fully contented and used to analyses and gauge the deviations of the processes [15]. Correlation analysis is one of the tools which is operated under the auspices of hypothesis testing with linear regression analysis. The correlation analysis results are shown in below table.

Table 4: Correlation's P & R-value.

Variable	P-Value	R-value	Relation
01	0.00	-0.943	Strong
02	0.550	-0.230	Weak
03	0.959	-0.020	Weak
04	0.561	-0.225	Weak
05	0.00	0.986	Strong

As a further matter, the analysis phase is crossed through R-square values which are given below table.

Table 5: Correlation's R-Sq. Value.

Variable	R-Sq. value
01	88.86%,
02	5.33%
03	0.04%
04	5.05%
05	97.31%

Having gone through the P-values, R-values and R-sq.-values, the two most effected factors have been seen to mitigate the paint fault.

V. SECOND MUDA (MOTION)

The lean six sigma is multifaceted approach, it is being applied in emergency departments of hospitals to lower the overcrowding problems [17]. The lean tool can easily be applied to empower the production effectiveness [5]. The second MUDA is motion in time i.e. To be catered to increase the effectiveness of SME which is about to be studied on existing operation layout of SME, the studied is contented with all operations which are being done there and time which is being consumed among the stations, the operation layout is taken to study it. The average time is taken which is being consumed after completion of each operation to next station, after considering the flaws of existing layout, the proposed layout is made on which the time values is taken again which are less than previous values and overall the total value or number is reduced, both layouts i.e. existing one and proposed one are drawn below.

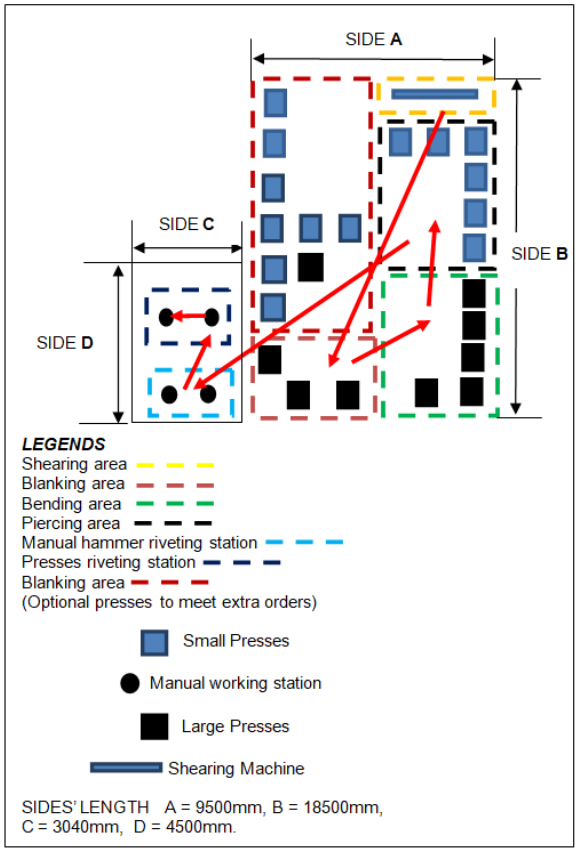


Fig. 2. Existing operational area layout.

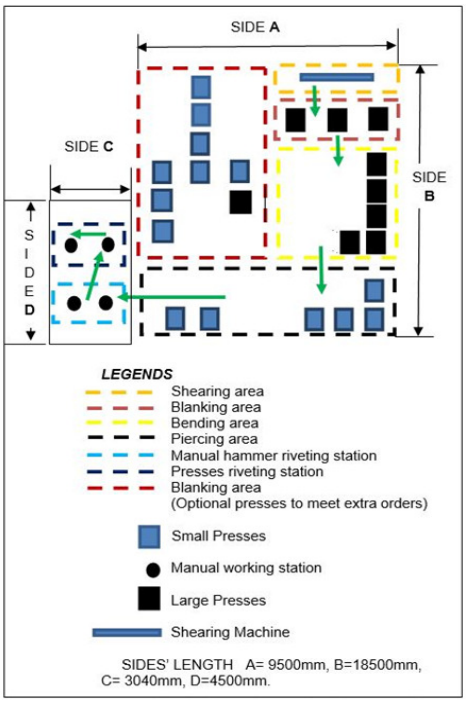


Fig. 3. Proposed operational area layout.

Table 6: Time on existing operational area layout.

Sequence wise operation numbers	Station	Average time
1.	Shearing to blanking	10sec
2.	Blanking to bending	04sec
3.	Bending to piercing	02sec
4.	Piercing to manual hammer riveting	08sec
5.	Manual hammer riveting to press riveting	03sec
6.	Press riveting to grinding	01sec
TOTAL		**28sec**

Table 7: Time on proposed operational area layout.

Sequence wise operation numbers	Station	Average time
1.	Shearing to blanking	2sec
2.	Blanking to bending	03sec
3.	Bending to piercing	03sec
4.	Piercing to manual hammer riveting	02sec
5.	Manual hammer riveting to press riveting	02sec
6.	Press riveting to grinding	02sec
TOTAL		**14sec**

VI. CONCLUSION

- Before start of the processes, the temperatures are taken i.e. phosphating temperature,
- The temperature of each process would be noted for record keeping
- Pictorial information is displayed at critical stations where the temperature is noted, pictorial information is just for the awareness of workers
- Overhauling of the machines are done through maintenance after defined period i.e. depends upon the utilization of machines and production targets

The lean six sigma study make help to explore the results of small manufacturing enterprise [23]. Results after implementation of lean six sigma approach as given below.

Table 8: First MUDA result.

Comparison	Yield %	Paint defects per Million opportunities	Sigma level
Existing	90.39 %	96031	2.8
Target	97.6%	23684	3.4

The result can be seen in Table 8, further, after study and measuring the lean six approach on first MUDA i.e. Paint fault, the relation of potentials which are directly linking to paint fault can also be measured through regression analysis equation which has been given below

Equation 01. Regression equation of paint fault for rejection rate% calculation

Regression equation of Paint fault for rejection rate %=–0.2617+0.001807 Process insufficient+0.000970 Paint layer

It is not the reduction of faults but also this approach will be helpful to reduce the rework cost and SME would get more revenue through financial impact [25].

For second MUDA i.e. Motion, at exiting plant layout is measured and proposed layout is studied and given in Fig. 3 Proposed operational area layout, to mitigate the excessive motion among the stations, the resultant values after comparing the before and after study are listed below in table

Table 9: Second MUDA result.

Sequence wise operation numbers	Station	Before	After
1	Shearing to blanking	10	2sec
2	Blanking to bending	04	03sec
3	Bending to piercing	02	03sec
4	Piercing to manual hammer riveting	08	02sec
5	Manual hammer riveting to press riveting	03	02sec
6	Press riveting to grinding	01	02sec
Results		**28sec**	**14sec**

Having using the same tools which have been taken in this research, the approach can be implemented to other small manufacturing enterprises to get the optimum targets.

VII. FUTURE SCOPE

Lean six-sigma is the leading approach in the world and this approach can cater all kind of problem at all type of work places. The small manufacturing enterprises are still back and lacking by this advanced approach. For this research only two MUDAs are taken for case study, the remaining MUDAs can be taken and mitigated by following the same foot-prints. The other MUDAS are,

- Overproduction
- Unused talent or manpower
- Inventory
- Over processing
- Transportation
- Waiting

On reduction of each above MUDA, small manufacturing enterprise (SME) can generate more revenue and use their resources in an optimum manner. Further, the major issue regarding small manufacturing enterprise is to collect the accurate data of any MUDA. Lean Six Sigma approach is systematic way which uses the existing mode of collection of data, for this improvement, industry 4.0 concept can be implemented to make the data more accurate in order to get the optimum outcomes, but the challenge could be investment related. This issue can be mitigated through proper study of return on investment to get the owner convinced. The lean Six sigma and industry 4.0 concept bilaterally can make small organization more profitable if the researcher could convince my making or showing good return of investment and somehow if the investment would be done through government programs specially for small manufacturing enterprises

Conflict of Interest. This is to certify that research with title “Analysing the effectiveness of Lean Six-Sigma approach on reduction of MUDAS (Wastes). A case study at SME (Small Manufacturing Enterprise) of Pakistan” is being attested by authors that they have no conflict of interests, regarding financial concerns and other kind of related disagreements with any organization, institutes, research labs and educational grants.

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