Utilization Improvement of Insulation Material Using Lean Six Sigma in Duct Manufacturing Company in Kuwait

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Abstract

Many companies are trying to increase their customer satisfaction, improve their system's performance and gain a competitive advantage by using different quality programs such as Six Sigma, which proved to be one of the most effective. The objective of this project is to solve the problem of the inefficient use of insulation material in a famous duct manufacturing company in Kuwait by the use of Lean Six Sigma DMAIC approach. Company XYZ has been suffering from about 22% waste in the usage of its insulation material that corresponded to an average of more than $42,000 per year. This project will illustrate the details of the different phases of DMAIC to investigate and solve this problem, along with illustration of all the tools used including process mapping, capability analysis, sigma level assessment, Ishikawa diagram and brainstorming to uncover potential causes, and redesign the current fabrication process with the aid of software to help the company plan their production efficiently and fulfill orders more quickly. When a fabrication facility optimizes its use of insulation material/sheet metal, costs go down because there is less waste and productivity goes up because jobs take less time. Also, benefits can include increased job satisfaction among employees and more satisfied customers. This study presents the impact of the Lean Six Sigma DMAIC on the company which will carry out a reduction in waste by 50% with a new sigma level of 4 instead of the current sigma level.

Keywords

Lean Six Sigma, DMAIC, Duct Insulation, Variation, Process Capability, Cause and Effect Diagram, Statistical Process Control (SPC). Production Planning, and Sheet Metal Fabrication software.

1. Introduction

Competitiveness is one of the most heard terms in today's industrial and manufacturing environments. Year by year, competitiveness between manufacturing companies is becoming more intense and in order for a company to survive it must maintain its competitive advantage. "In today's competitive environment the prices, services, promptness and performance of the product are major factors," (Khekale, Chatpalliwar, & Thakur, 2010). That is, companies must always satisfy their customers by providing high quality products and services with the least possible price. Unfortunately, companies all over the world are suffering from hidden and frequently occurring problems such as low productivity, low production rates, high defect rates, high percentage of waste, inefficient use of material etc. Those problems cost companies thousands and sometime millions of dollars per year. This money could have been spent on investments that can help the company maintain its competitive advantage such as purchasing modern and up to date machines, hiring new well-trained personnel, launching new factories, work systems and many more. As a result, companies are implementing six sigma projects to help them identify and solve the previously mentioned problems. Six Sigma is an innovative method of quality management that has been introduced in Motorola by Bill smith and Bob Galvin (Schroeder, Linderman, Liedtke, & Choo, 2008).It is a set of methods and techniques that aim to improve process performance through the reduction of the variation in the quality characteristic of interest (Montgomery, 2013). Statistically speaking, in order to achieve Six Sigma the objective is to make sure that the process being studied should not produce more than 3.4 defects per million opportunities (DPMO) along with a success rate of 99.9997% (Moosa & Sajid, 2010).

This objective can be reached through a variety of approaches, one of which is the DMAIC approach .DMAIC is a systematic six sigma approach that consists of 5 phases: Define, Measure, Analyze, Improve and Control. This approach help the implementers tackle the problem in a step-by-step basis .the unique thing about the approach is it guides towards finding the possible root-causes of a problem, hence proposing and implementing the optimum and feasible solution to eliminate them by maintaining a continuous improvement (Ren Jie, Kamaruddin, & Abd Azid, 2014).

2. Literature Review

Many case studies with different topics were searched but at the end they all have the same concept and meaning, which was easy to compare and link to the topic usage improvements and insulation material using lean six sigma in a duct manufacturing company. The steps before applying the DMAIC process, is to understand clearly what lean six sigma is and how it can be applied to the project. One of the articles discussed paper manufacturing company which was about how they had poor cutting techniques and poor printing procedures, that is why the company used the procedure DMAIC to enhance the performance and minimize all types of waste. As (Mandahawia, Fouad, & Obeidat, 2012) explained, this resulted that the overall equipment effectiveness enhanced to 21.6% for printing and 48.45% for cutting, also by using 5S procedure new working methods were explained. Moreover, in the second article it discussed the implementation of lean six sigma to reduce waste and analyse the root cause of the waste in a concrete panel production manufacturing company. They concluded that the problem of the waste can be solved by training workers and organising the manufacturing company (Oguz, Kim, Hutchison, & Han, 2002). Another case study that took place in Saudi Arabia, studied the problem of the inefficient usage of flour in a biscuit manufacturing company, they approached the problem through the six sigma DMAIC approach and managed to identify the root causes of the problems of the waste and helped the team develop a check list of procedures that include guidelines to help minimize and control the flour waste (Emad Abouel Nasr, 2016).

3. Case Study and Methodology

The case study of interest is about company XYZ. It is a Kuwaiti Company that manufactures several products of which it includes: ducts, stainless steel kitchen units/compartments, they also offer maintenance services and project divisions. Ducts and stainless steel holds the biggest source of income profit for the company, 50% of the profits are from ducts and 20 % are from the stainless steel. Some of the biggest customers of the company include big petroleum companies such as KOC, KNPC, large food chains such as Apple Bees and Burger King, and they get involved in large projects such as Jaber Al Ahmed Cultural Centre and Al Shaheed Park. The company has only one factory that contributes in the making of all the mentioned above products. The company has local and international suppliers. For the ducts, the main international suppliers are: SABIC from Saudi Arabia and Nippon from Japan. Recently the company witnessed problems regarding its insulation material usage and to start tackling this problem DMAIC will be applied. DMAIC is an acronym stands for Define, Measure, Analyze, Improve and Control. These are logical phases that will lead the project team from defining the problem through implementing solutions linked to underlying causes, and establishing best practices to make sure the solutions stay in place” (Michael L. George, 2005).

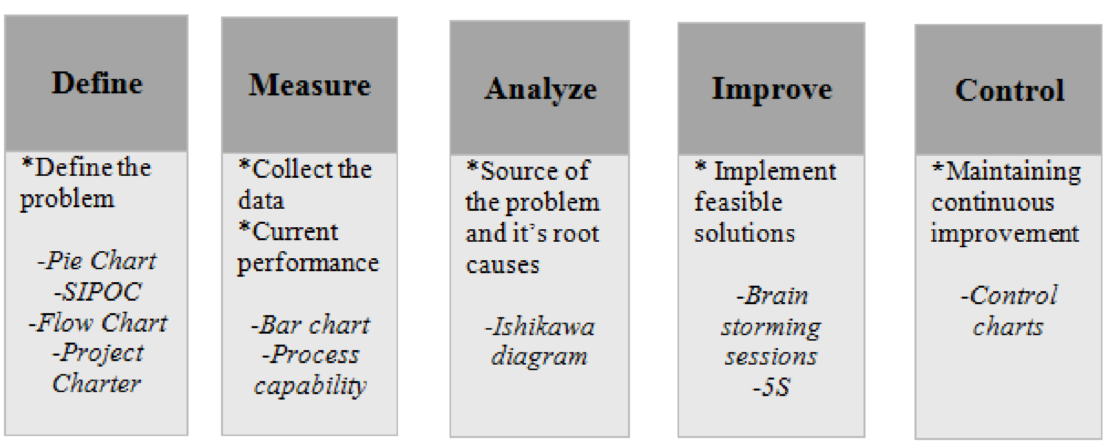

Figure 1: The DMAIC phases and examples of the tools used in each phase

4. Description of the Manufacturing Process

As previously mentioned, the company is specialized in ducts manufacturing. First the metal sheets used in ducts manufacturing arrive to the factory, those sheets are either imported from Japan or Saudi Arabia. The metal sheets are then cut according to the design requirements and customer specs. The factory uses three different ways of cutting:

- Manual cutting for short and simple metal cuts.
- Cutting machines for long straight cuts.
- Plasma cutting machine for curved and sophisticated cuts.

The sheets that were cut are then moved to the insulation area. The insulation area consists of two main workstations: the cutting work station and the fitting work station.

- In the cutting work station, the insulation material called "acoustic" is cut according to the specs and sheet size. This is the step where the waste occurs. Afterward, both the metal sheets and the insulation material that was cut is moved to the fitting workstation.
- In the fitting workstation, the insulation sheets are added and stuck to the metal sheets by glue and supported with wire mesh and sticker nails .Wire mesh and sticker nails are to prevent the deterioration of the insulation material over time due to the pressure of the air passing through the duct.

Finally, the sheets are combined together to form the duct and the finalized ducts are weighted and sent to the customer. It is important to note that all the operations in the insulation workstations are done manually; it does not involve machines nor automation.

Figure 2. Ducts Manufacturing Process

5. Application of the Lean Six Sigma DMAIC

5.1 Define Phase

The first phase in the DMAIC approach is the define phase. This phase aims to create a clear project charter that includes the project's problem, goal, and quality characteristic of interest, financial benefit, scope, and team members. XYZ is a Kuwaiti Company that manufactures several products of which it includes: ducts, stainless steel kitchen units/compartments, they also offer maintenance services and project divisions. Ducts and stainless steel holds the biggest source of income profit for the company, 50% of the profits are from ducts and 20 % are from the stainless steel as seen in Figure: 3.
Even though ducts hold the biggest share of the company's profit the company is witnessing a difference between the actual and required insulation quantities being used. As a result, the demand of the insulation materials fluctuated in an unacceptable manner. This shows that a quantity of insulation material is being wasted and lost during the manufacturing processes. The aim of our project is to develop and implement solutions to achieve a more efficient usage of the material used in the insulation used in ducts manufacturing. Hence, greatly improving the company's profitability.

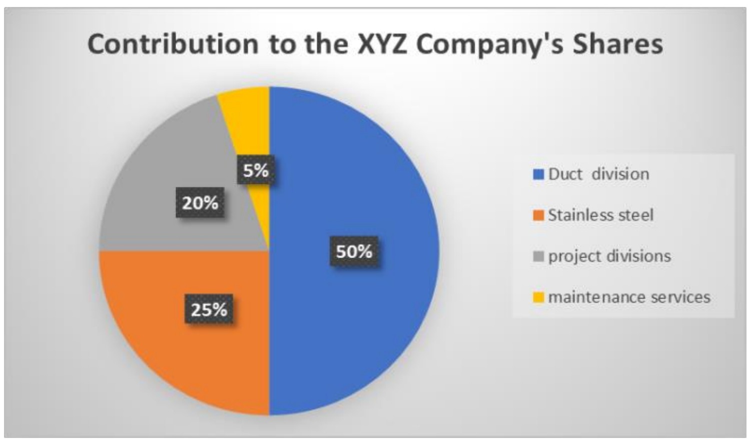

Figure 3. Contribution to the XYZ Company's Shares

To get a better understanding of the manufacturing process of interest and to be able to specifically determine the scope of the project, the six sigma team constructed a SIPOC. A SIPOC (Suppliers, Inputs, Process, Outputs, and Customers) is a high-level process map used to identify the input and outputs of the process and helps the team agree on a project boundary (Smew, et al., 2018). The SIPOC of the process of interest is show in Figure 4. This was done with the help of the stakeholders: the company's cost accountant, production manager, factory supervisor and the six sigma team. It was then decided that the project is concerned with the highlighted process, cutting the insulation material, which is the main source of waste in this project.

5.2 Measure phase

The measure phase is the second phase in the DMAIC approach .In this phase, data regarding the quality characteristic of interest is collected in order to:

- Understand the current performance of the process.
- Determine the baseline of the current process performance.

5.2.1 Data Collection

According to the project chairman, the company's demand of insulation material has fluctuated dramatically in an abnormal fashion, which made her suspect that the insulation material is used inefficiently in the factory. In order to find an answer for the chairman's doubts, the team decided to use data that has been collected over the past 9 months regarding the following:

- The amount of insulation material "required" to be used.
- The amount of insulation material "actually" used.

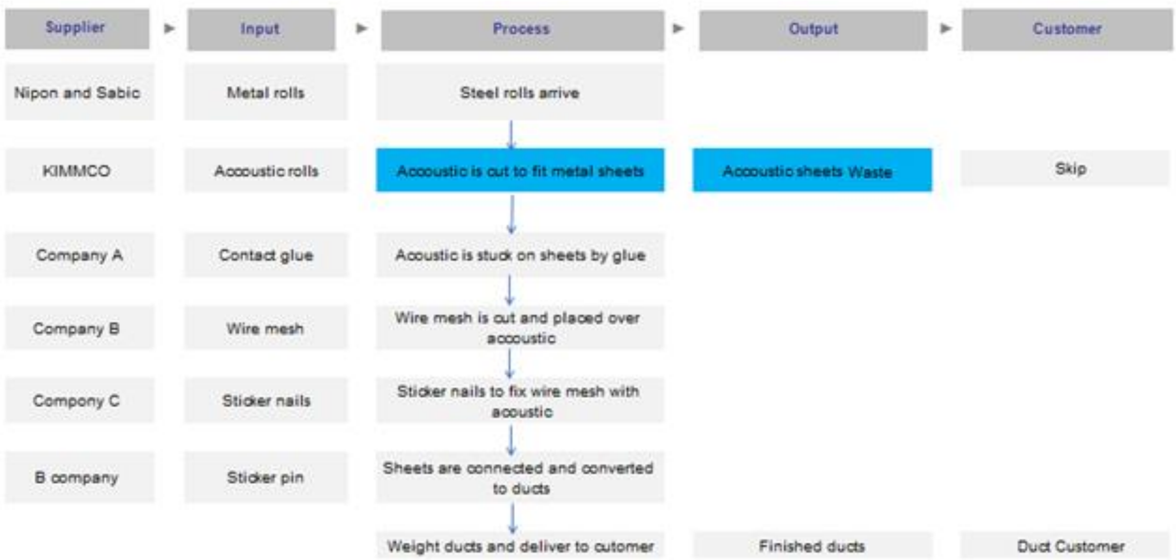

Figure 4. SIPOC

The team must first make sure that the variability in the data reflects the variability in the process of interest ,and it is not the result of the variability in the measurement system . This is a vital step in any six sigma project in order to avoid any wrong conclusions about the process. Since the data used in this project is historical data, the team checked that the data used is sufficient, reliable, relatively recent, and in the proper format. The team got full access to the records of the company, the data in those records represented the overall behavior of the system.
The difference between the material required to be used and the actual amount used for different periods are shown in Figure 5 as follows:

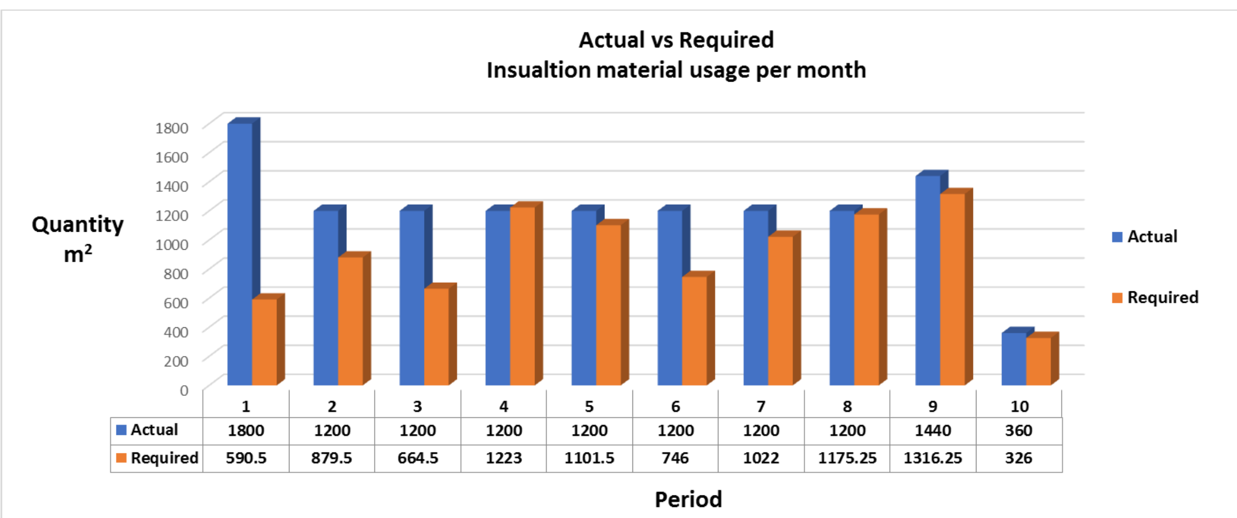

Figure 5. Actual vs. required insulation material usage per period

The two quantities are then to be subtracted from each other in order to calculate the insulation material waste percentage using the following formula:

$$Actual\ usage - \text{Required usage} = \text{WASTE!!}$$

5.2.2 Baseline of the Current Performance In Terms of Sigma Level

The quality characteristic of interest is the amount of insulation material wasted. The team decided to count the wasted material in terms of its area in m^2 .This means that the data dealt with is counted data; so it is considered attribute.

Since the used data is of type attribute; process capability cannot be calculated. In order to determine the sigma level of the current process performance, the DPMO (Defects per million opportunities) of the process must be calculated first. This was done according to the following procedure:

1. For each of the studied periods, the waste percentage was calculated through the formula shown below. The results are shown in the table below.

$$\%Waste = \frac{Actula - Required}{Actual} \times 10$$

Actual used	Required to be used	Waste	Waste % per period
1800	590.5	1209.5	67.19
1200	879.5	320.5	26.71
1200	664.5	535.5	44.63
1200	1200	0	0.00
1200	1101.5	98.5	8.21
1200	746	454	37.83
1200	1022	178	14.83
1200	1175.25	24.75	2.06
1440	1316.25	123.75	8.59
360	326	34	9.44
			22.0

Table 1. Calculating waste percentage

2. The waste was found in the term of a percentage. The average of the waste percentage was then calculated and found to be **22%** of waste during the given period of study.
   The average of the waste percentages was calculated due to the variation in the reorder point .
3. The percentage of waste for each period was then multiplied by million to find the corresponding DPMO for each period.
4. To find the DPMO that reflects the overall performance of the system, the average of the periods' DPMO's was calculated and it was found to be **219503 defective parts/million.**
5. Using the sigma level conversion table ,the sigma level that corresponds to the calculated DPMO was found to be **2.2$\boldsymbol{\delta}$**.

This sigma level is an evidence of the poor state of the system and that the variation in the system is dangerously high.

5.3 Analyze Phase

Brain storming sessions were conducted with the company's mangers and stake holders to identify all possible root causes of the problem and an ISHIKAWA Diagram was constructed as shown in Figure 6.

After deciding on all the possible root causes of the problem, it was decided to focus only on the main issues that would contribute mostly in improving the system. Focusing on 20% of the problems can lead to an 80% improvement in the whole system (Pareto Principle). The root causes were: bad stock control and reorder level, poor documentations, poor production planning, lack of feedback, lack of training, poor housekeeping, lack of standardized cutting procedures and lack of automation.

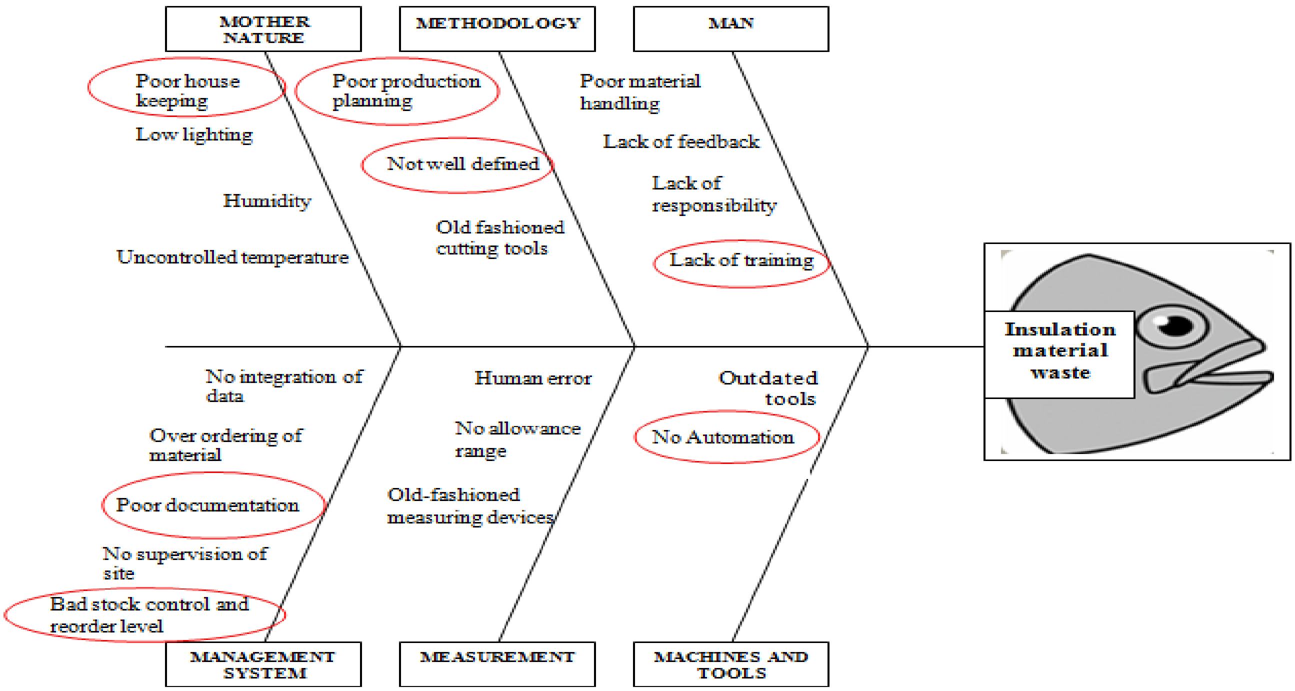

Figure 6. ISHIKAWA Diagram

5.4 Improve Phase

The main goal of this phase is to implement the best solutions with controlled risk. By optimizing the use of insulation sheets the costs will go down due to a decrease in the waste being produced and productivity increases as the jobs will now take less time. Not only will the improvement decrease the company costs but it can also increase job satisfaction among employees and lead to more satisfied customers. The suggested solutions are based on the results of the analyze phase. The stakeholders along with the six-sigma project team held brainstorming sessions and suggested possible solutions for the different root causes identified in the analyze phase. Due to the limited time and resources, the six-sigma team usually focuses on solving the vital few root causes based on the Pareto principle.
In our project, and according to the root causes identified, we came up with the following scheme, Figure 7:

Figure 7. Project Scheme to Solve the Waste Problem

1. The current system involves manual cutting of the insulation material so the insulation sheets are greatly affected by the subjective judgment of the worker as shown in Figure 8 therefore, the area/space of the insulation material sheet is not well utilized. Sheet metal fabrication software is recommended to be used to make use of all the available sheet area in the most optimum way. It does so by, minimizing the tool paths. Software, as in Figure 9 allows the employee to import complex parts from CAD programs or design parts into the application itself, the sheet metal software then places parts optimally on the available sheets therefore maximizing the sheet utilization. SMP/IS software allows the facility to reduce the scrap rates up to 8%. (Better Sheet Utilization).

Figure 8. Current System of Cutting (canstockphoto)

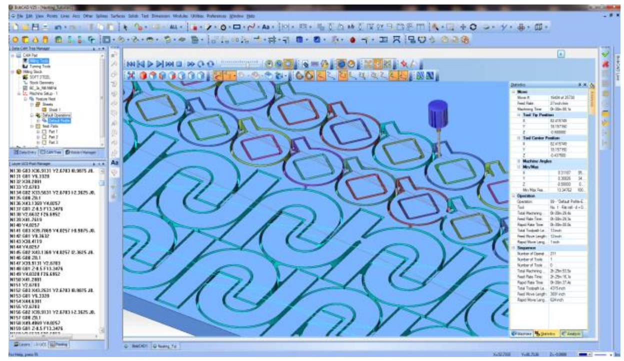

Figure 9. Cutting using CAD (BobCAD-CAM)

2. The inefficient use of the insulation material is mainly happening due to the fact reordering levels were not standard with a fixed amount nor were they monitored, and workers made orders whenever they felt so. To solve this issue, strict rules for monitoring reorder levels must be applied. Workers must only order exact amount of insulated material needed, no more, no less. A reorder level supervisor should be hired to approve if a reorder is actually needed and to set stock level control policy.
3. As previously mentioned, workers do not follow a standardized way of cutting, and cutting varies greatly among workers. The majority of the workers are not aware of the principles of optimum space utilizations and the insulations sheets are cut randomly. The company must include training sessions for workers to show them the best and the right ways of cutting the insulation material with the least possible waste. The system is supposed to make the workers more skilled and will help reduce any production errors that may lead to additional rework.
4. Another major reason of the martial waste was the lack of feedback between the management and the workers in the duct factory along with the poor documentation. A feedback system or procedure must be applied to facilitate the communication between the management and the factory workers. This will help keep the management updated with the material usage, and it will interfere if the used quantities were not normal. Beside the communication procedure, the company should have a data base of the quantities of material used so that all the usage information can be integrated, and trends can be spotted. The data base will also help the company easily identify any problems or waste that may occur.
5. One of the main reasons causing waste in general is the cluttered and untidy work place. In this kind of environments, it becomes really hard for employees to notice the waste or monitor material usage. To solve this issue, it is proposed to implement 5S. This is a lean tool that usually has a great effect in reducing the waste in facilities. It consists of sort, set in order, shine, standardize, and sustain. The raw material (including the insulation material) must be sorted and ordered. The company must assign personnel to clean the work place and any waste must be disposed of immediately, clutter must be eliminated. Standard procedures for cleaning, sorting, and decluttering the row material must be applied. And all the previous actions must be maintained. A cleaner work place means less waste in raw material, Figure 10.

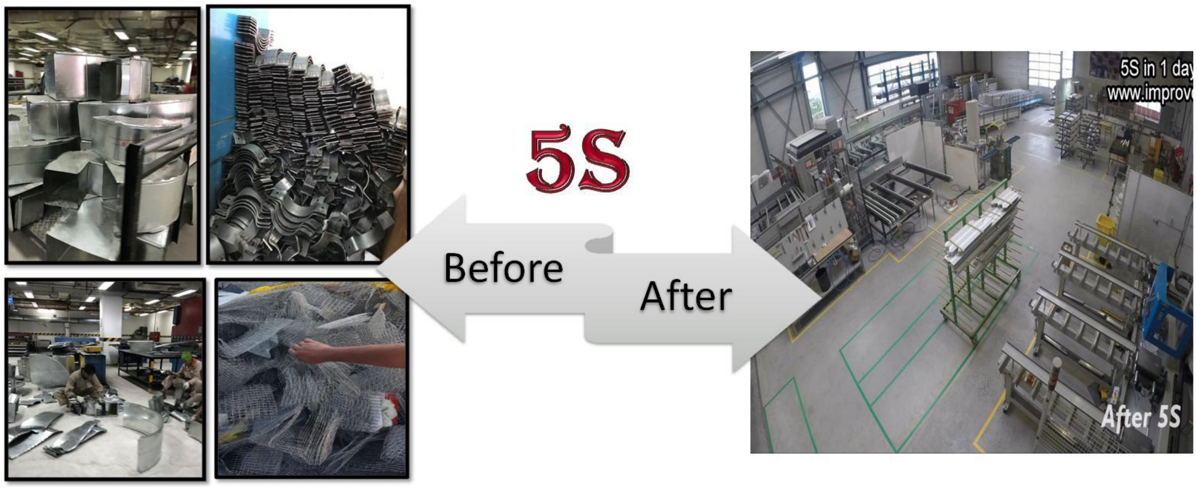

Figure 8. The System Before and After the 5S

6. Since waste in manufacturing environments cannot be completely eliminated, it still can be minimized. One effective way that will help the company achieve a better control on the insulation waste is through setting an allowance or a limit for the waste levels which should be always observed and maintained within those limits through a firm and strict Standard Operating Procedures (SOPs) to be applied during the control phase of the project and afterwards.

5.5 Control Phase

The final phase in the DMAIC is the control phase. The main goal of this phase is to maintain the new improved state of the system and prevent the problem from arising again. After discussing the phase goals with the managers and stakeholders, it was decided that the best way to monitor and maintain the gains from our project is by developing SOPs that will provide clear steps to be followed whenever the waste starts to evolve beyond the proposed limits as an immediate action to deal with it at the source before it exacerbates.

Next to implementing the changes they should be controlled to check if they influence the production process positively and bring any profits to the company. This can be done by creating a control plan where it should be exactly define what data, how, how often and who should control it. If any non-conformance is detected, instructions regarding needed actions to undertake, should be also included. Over time, such a plan should be updated depending on the evaluations after its implementation.

6. Conclusion

In this project, Lean Six Sigma DMAIC was successfully implemented in a duct manufacturing company in Kuwait to help them improve the inefficient usage of insulation material. The problem of interest resulted in a waste of 22% of the insulation material that corresponded to an average of more than $42,000 per year. The problem statement of the project along with the project stakeholders, scope, objectives and time frame were specified in the define phase through creating a clear project charter and SIPOC. In the measure phase, the baseline performance of the system in terms of a six sigma level was specified .This was done through collecting the actual and the required amounts of insulation material used in the manufacturing process over nine months. The data was historical, no samples needed to be collected or investigated. The difference between the actual and required materials used in each period was calculated and turned into a sigma level, which in our case turned out to be 2.2 sigma, and the average percentage of waste was quantified and turned out to be 22%. The root causes of the problem were then identified by conducting brainstorming sessions with the stakeholders, and an Ishikawa diagram was constructed .This helped the team visualize the causes and their categories. The most important causes the team considered in the study were based on the discussion with the stake holders and they were: Lack of feedback, Poor production planning, bad stock control, poor monitoring of reorder levels, and lack of automation. Those identified root causes helped the team suggest solutions for the problem. Meetings with the stakeholders were held, and the following solutions were suggested: Implement a new system of material usage using CAD, strict rules for monitoring reorder levels, train workers to follow new system, Increase feedback between management and workers, set limits or allowances for waste, and implement 5S. Standard operating procedures are to be developed in the control phase, to make sure the improvements in the system are maintained. The suggested solutions promising to reduce the waste percentage from 22% to 10%, and improve the performance of the system to become 4 sigma level instead of 2.2, saving the company an average of $42,000 per year.

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Biographies

Nourhan Hassan, Lina Hamdan, and Noor Khourshed are recently graduated students from the American University of the Middle (AUM) in Kuwait, majoring in Industrial Engineering. During their four years of study they gained several engineering and computational skills. They worked with computer software such as MS Office, AutoCAD, Minitab, MATLAB, Arena, FlexSim, Solid works, Jack, and Visual Studio. They participated in many AUM academic activities and in addition to their major graduation project presented in this paper, they worked on several course projects in the area of manufacturing processes and robotics, safety and ergonomics, operation research, quality control, simulation, and lean six sigma. Recently Nourhan Hassan and Lina Hamdan won the first place of the Simulation Research Competition in IEOM 2018, Bandung-Indonesia.

Walid Smew is an Assistant Professor in Industrial Engineering at the American University of the Middle East (AUM), Kuwait. He earned B.Sc. and M.Sc. in Industrial and Systems Engineering from Benghazi University, Libya and PhD in Lean Supply Chain Management from the School of Mechanical and Manufacturing Engineering in Dublin City University (DCU), Ireland. Dr. Smew is a Chartered Engineer and member of Libyan Engineers

Association, he is also a certified Lean Six Sigma Greenbelt and Product and Process Validation engineer in Ireland. Dr. Smew has published several journal and conference papers and supervised many graduation projects. He has an excellent experience, both theoretically and practically, in machining and metal forming operations and the application of Lean Six Sigma for problem solving and finding optimized solutions through the application of different statistical techniques. Dr. Smew provided technical guidance to assembly processes using work measurement techniques to identify opportunities to improve production performances in terms of time and cost. Dr. Smew has done consulting in the area Supply Chain Management (SCM) and Simulation Modeling along with Dr. John Geraghty from DCU; they developed a comprehensive production and distribution simulation model for Ireland's future oil supply on behalf of Byrne Ó Cléirigh for engineering and management consultancy. Dr. Smew research interest include Quality Control, Lean Six Sigma, SCM, Manufacturing Processes, Simulation and Optimization. Recently Dr. Smew and his research project colleagues won the first place of the Undergraduate Research Competition in IEOM 2018, Bandung-Indonesia.