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The Productivity Performance's Measurement in SME Industry by using DMAIC of Six Sigma

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Abstract: ***It is crucial that Malaysia's Small- Medium Enterprises (SME) in the manufacturing sector could achieve desired productivity rate as this could contribute not only to the country's Gross Domestic Product (GDP), but also could contribute to the spending power of a nation. It is important for SME manufacturers to stay ahead in the ever-competitive market to ensure their survival and provide countless jobs for the nation. The objective of this paper is to study, analyse and propose viable solutions to improve manufacturer performance in terms of productivity and quality in the manufacturing sector by using various operation management tools. Hence, one SME company was chosen by utilizing the Value Stream Mapping (VSM) in DMAIC approach to measure their productivity. The aerosol production line was study, to see the gap measurement in productivity before and after applying a systematic method in operation management. Furthermore, along with various operation management tools such as Kaizen, Kanban system and 5S, a new layout (VSM) for the production line was proposed. Result shows that the proposed new layout could reduce the distance travelled by operator by 22.26 %, at the same time will increase the productivity and quality of product. Since the overall performance of the aerosol grease production line will be improved, the waste found in the production line also will be alleviated***

Index Terms: ***DMAIC Approach, Increase Productivity, Process improvement, Production Layout Improvement, SME in Malaysia, Waste Reduction***

I. INTRODUCTION

This is a case study explaining about the successful implementation of the DMAIC approach to segregate the problem-solving process systematically and develop a set of solutions to be proposed to solve the issues faced in the grease type aerosol lubricating spray production line at the case study industry plant. All manufacturing processes will have unique problems that will require different methods or tools to solved by utilizing suitable operation management (OM) tools to overcome the problems. By overcoming the issues faced in the production line, the performance of the manufacturing process can be improved.

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Problems such as high number of defects, reworking, unsuitable facility layout, unoptimized cycle time or unpredicted down time can bring detrimental effect to any manufacturing process and it is the goal the goal of any production line is to increase productivity and maintain high quality standards.

II. THEORITICAL APPROACH

Dmaic Approach

The acronym DMAIC is well known among Six- Sigma practitioners and production planning experts. DMAIC is consists of five process to bring improvement, namely Define, Measure, Analyse, Improve and Control[1][2][3]. The data used for DMAIC must be quantifiable and the process must be defined, else it is impossible to measure [4]. A summary of DMAIC processes and descriptions is found in Table.

Table. 1 Summary of DMAIC processes and descriptions

Process	Descriptions
Define	In the define stage, the problem to be solved using DMAIC, limitations of organization, project scopes and improvement opportunities in the process was identified.
Measure	Collection of qualitative data is to be done in the measure stage. Using the qualitative data collected, problems in process can be identified in the next stage which is analyse stage and goals for improvement could be proposed in the improve stage.
Analyse	The data obtained from measure stage will be analysed. Any gap for improvement between the current process performance and targeted process performance was identified.
Improve	Solutions or improvements towards the current process was developed and proposed to the organization in this stage.
Control	Once the relevant improvements are found for the production process, measures to control the improved process was proposed. Total control must be established to ensure successful implementation of improvements.

III. METHODLOGY

Any process or activity that does not add value to a product from the view of consumers is called waste. All waste should be avoided as lean manufacturing focuses on only having value-added activities, with no rejected products and no inventory. But unfortunately, there will be some waste that are absolutely necessary to add value to the organization but not towards the products produced [5]. The seven types of '*Muda*', which means waste in Japanese as identified by Taiichi Ohno which are overproduction, queues, transportation, inventory, motion, over processing and defective products[6].

Table. 2 Types of waste and description

Type of Waste	Description
Overproduction	Products are produced more than the customer's order or produced before it is in demand. Overproduction is a result of inaccurate forecasting, preparing excess stock to face sudden raise in demands and also not wanting to change the tooling of the production line frequently to produce different products.
Queues	Queues are also known as waiting. Waiting time or idle time in the production process which are not adding value to product. Any employee or machine that is not working will not be contributing to adding value to products, causing waiting or idle time. Queues can also be a result of bottleneck in the process, machine down- time, pending information from management and late delivery of raw materials.
Transportation	Transportation of materials, parts or finished products between one place to another unnecessarily adds no value to product. This waste may be due to poor facility layout that requires employees to move raw materials, parts or products from one place to another in the production facility or unstrategic facility location that requires extra logistics services.
Inventory	Any excess raw material, parts, work-in-process (WIP), finished products does not add value to products, at the same time withhold liquid assets of the organization. Inventory also uses up valuable spaces in the warehouse, causing a lack of storage space for the organization.
Motion	Unnecessary movement by the employee or machine that does not add value in producing the product. Production lines that require operators to reach for materials or parts that are not placed at ergonomic position will cause unnecessary movement and also operators' risk of injury will be increased.
Over processing	Unnecessary process performed on the product that does not add value. These unnecessary processes incurred could be done by employee or machine.
Defective Products	Reworking or scrapping defective parts and warranty claims or returns that are the result of defective products. Defective products are the result of products produced does not comply with the quality.

IV. RESULT AND DISCUSSION

Define Process

In the production line which is the focus of this study, the main products being produced are the grease type aerosol lubricating spray. There are a total of five different process required to complete the product. Based on observations performed on- site, it was found that the production line is in the form of many isolated islands instead of a continuous flow. Waste in the form of transportation and motion is found in the original layout of the production line due to undesired and optimized placement of machines, furniture, storage racks and inventories at the aerosol production line that caused operators to perform unnecessary motion while shifting from one process to another and also while working at one particular process.

Table. 3 List of process and machine involved in the aerosol production line

Process	Machine involved
Filling grease into aerosol canisters.	Horizontal positive displacement grease filler 1
Crimping of valve cap to canister	Aerosol canister crimping machine
Filling propellant into aerosol canisters.	Through the Valve (TTV) gassing machine
Spray nozzle (actuator) installation and labelling of canisters.	None. Manual labour is utilized.
Heat shrink wrapping	Heat shrink wrap packaging machine

A sketch to illustrate the original layout and motion of operator for the production line was done on site and is shows in Fig.

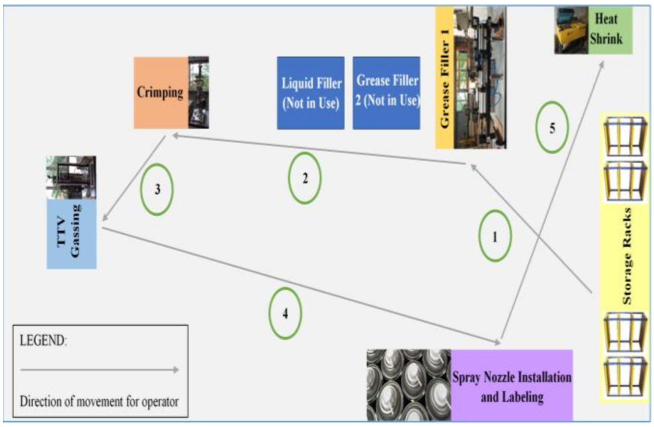

Fig. 1 Original layout of the aerosol production line

Apart from the layout issues in the production line, it was observed that the aerosol production line produces other waste that are defined in the lean engineering context. Wastage in the form of queues occurs during the unfortunate case of machine breakdown.

Measure Process

Current state value stream mapping (VSM) of the aerosol production line was constructed based on observations and data obtained during walks at the production line floor. A tabulation of basic data obtained to facilitate the construction of VSM is illustrated in Tableas follows.

Table. 5 Data obtained to facilitate the construction of VSM

Data	Calculation Working
Customer Demand Per Shift	Demand per month/Working days per month = 30000/22 =1364 canisters
Available Work Time Per Shift	8-hour shift per day =28800 seconds = 480 minutes
Takt Time	Available Work Time Per Shift/Customer Demand Per Shift = 28800/1364 =21.11 seconds =0.35 minutes

It was agreeable that VSM enables users to easily identify the different types of time available in the production process and could bring improvements to an organization's production process [7][8][9][10][11]. The current state VMS of the aerosol production line produced is shown in Fig.

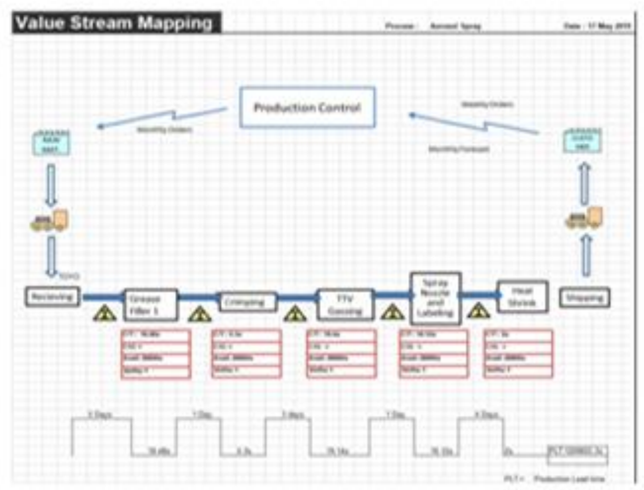

Fig. 2 Current state VSM of aerosol production line

Analyse Process

A detailed original layout was plot using CAD software to illustrate the total motion path of the operators in the production line. It was found that the total distance travelled by the operators are approximately 32.8 m and there is an intersection of path when operators travel from the labelling station to the heat shrink station, creating waste in terms of transportation as operators might collide into one another. Certain processes in the aerosol production line such as the spray nozzle installation and labelling process is not very ergonomic as it's required to perform the process and reach for raw materials at unsuitable work positions, thus causing waste in terms of motion.

From the VSM generated, it is observed that there are much inventory and waiting in the production line. Although the process cycle time for each process is less than 30 seconds for all five processes, the inventory available is for a few days. This created much waiting time and in end, causes work in progress inventory to build up and wastage of space.It was also found that over processing occurs during the grease filling and TTV gassing stage as the operators are required to inspect the mass of every filled canister to ensure the correct amount of grease is filled after the grease filling processes and propellant is filled for each canister, ensuring product quality. To plot a cycle time details graph, parameters such as value-added time, non-value-added time, and lead time was calculated.

Table. 5 Calculations based on data obtained from VSM

Parameter	Calculation
Value Added Time	ΣValue- added- time =18.48s+5.3s+19.14s+10.12s+2s =55.2 seconds =0.92 minutes
Non- Value- Added Time	ΣNon-value- added time =5 days+1 day+3 days+1 day+4 days =14 days =120960 seconds =2016 minutes
Lead Time	Value added time+non-value- added time =55.2s+120960s =121015.2 seconds =2016.92 minutes

A cycle time details graph as shown in Fig. was plotted to illustrate the average cycle time for the five processes that are in the aerosol production line for the production of aerosol grease. The X- axis of the graph signifies all the processes available in the aerosol grease production process and Y- axis signifies the cycle time in seconds. It could be observed from the graph produced that the longest cycle time occurs in the TTV gassing process, then followed by the grease filling process. The total cycle time and takt time was also plotted in the cycle time details graph.

The relationship between the takt time and total cycle time was also illustrated in the cycle time details graphs. It was found that the actual total cycle time to complete one canister of aerosol grease is significantly higher than the takt time of the production line. This result demonstrates that the production line is undesirably understaffed.

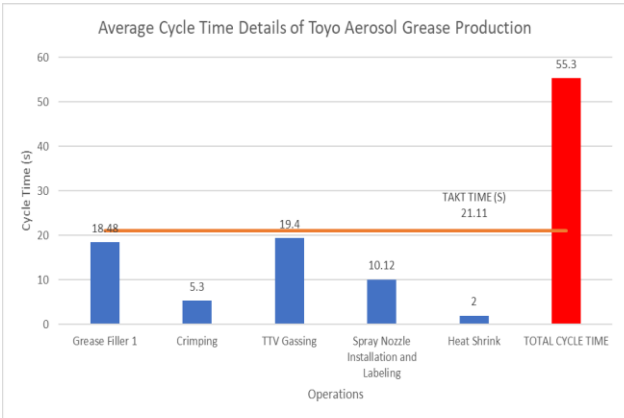

Fig. 3 Cycle time detailed graph of aerosol production line.

From the analyse process, it was found that all waste found in the aerosol production line is of type 2 'Muda' as defined in the literature review section. A summary of all waste found in the aerosol production line in accordance with the theory of 7 wastes in lean manufacturing is summarize in the Tableas follows:

Table. 6 Summary of type of waste found in aerosol production line of interest

Type of Waste	Description
Transportation	Unsuitable production layout that causes unnecessary need to transport unfinished goods from one process to another
Inventory	Too much work in progress, which resulted in excess inventories in process.
Motion	Certain processes such as the spray nozzle installation and labelling process is not ergonomic for operators, as they are required to perform the process and reach for raw materials at unsuitable positions.

Queues	Queues that causes waiting in production line occurs as there are excessive work in progress inventories and in unfortunate cases of machine breakdown
Overproduction	Overproduction at crimping process due to inability of the gassing process that occurs right after the crimping process to keep up with the volume of crimped canisters being supplied, causing a bottleneck to buildup.
Over processing	Occurs during the grease filling process and propellant filling TTV gassing process as operator is required to manually weigh the mass of each canister to ensure required amount of grease and propellant is filled.
Defect	Defects caused by accidental dropping of canisters during transportation of unfinished goods from one process to another.

Improve Process

The layout of the production process was proposed to be redesigned into a U-shaped production process layout to transform the production process of many isolated islands to a continuous flow production process layout. This could be achieved by rearranging the optimizing the placement of machines, furniture, storage racks and inventories at the aerosol production line that causes operators to perform unnecessary transportation and motion while shifting from one process to another. A single flow U- shaped production process layout could reduce waste in terms of transportation as distance from one process to another is reduces and intersection of paths could be avoided. U- shaped production processes are proven to improve labour productivity as proven in other publications[12]. A U- shaped production layout was suggested due to space constrain at the site. It was found that the total distance travelled by operator to be at 25.5 m, which is 22.26 % shorter than the original production line at 32.8 m. This will contribute to a reduction in transportation and motion waste. The improved layout of the aerosol production line is presented in Fig. as follows.

Fig. 4 Improved layouts for aerosol production line

From the obtained takt time and total cycle time, it was determined in the analyse phase that the aerosol production line is understaffed. A minimum of 3 staff are required for this line to achieve the required customer demand, in end reducing queues and waiting time. It is suggested that an additional operator is hired to overcome this issue. Cross training to increase worker flexibility can also be considered to ensure that not just one operator is knowledgeable in handling a particular machine so that the production process could still function in case of workers being absent for duty.

To solve the issues of inventory, overproduction and unfinished goods being transported in unsuitable cardboard boxes, it was proposed that the case study industrial plant could utilize the Kanban system to control inventory through the production line which was discussed in the literature review section. The Kanban system is proven to reduce waste and optimize operational cost in a Malaysian SME in the publication Lean Manufacturing Case Study with Kanban System Implementation [13]. The issue of over processing that occur when operators are required to manually measure the mass of every single canister after the grease filling and TTV gassing process could be overcome by upgrading to semi- automatic Machines, the quality of product could also be ensured as the filling process is done more accurately by the machine. Total preventive maintenance (TPM) is highly encouraged to ensure that all machine and equipment used in aerosol production line is maintained well and is functioning correctly. A scheduled preventive maintenance plan should be developed to ensure each productivity of machine is maintained correctly at the right interval to minimize downtime. The implementation of TPM in organizations is proven to reduce accusations and avoidance of responsibility among employees when machine downtime occurs and reduces downtime, thus reducing waste [14][15][16].

5S is also proposed as a method to improve the production process and reduce waste, shifting the aerosol production line one step closer to lean manufacturing. 5S is not only a method to improve the overall aerosol production line but it is also a very good culture organization. Wide to be practiced in any organization as it encourages the involvement of all individuals in the organization to strive for improvements towards not only the products produced by the organization, but also the housekeeping, maintenance, performance, working environments and conditions[17]. 5S is easy to understand and simple but should be approached step by step in a practical way and reinforced in the organization's working culture to ensure its success.

A summary of improvements proposed to overcome all 7 different types of waste found in the aerosol production line is in Table as follows.

Table. 7 Summary of the proposed solutions for the 7 wastes found in the aerosol production line

Proposed Solutions	Transportation	Inventory	Motion	Queues	Overproduction	Over process	Defect
U- Shaped Production Line	✓		✓				
Additional Operator				✓			
Increase Worker Flexibility				✓			
Kanban System		✓	✓		✓		✓
Upgrade Machines in the Aerosol Production Line						✓	
TPM				✓			✓
5S	✓	✓	✓	✓	✓	✓	✓

Control Process

In the control phase, continuous improvement, also fondly known as Kaizen in the field of operation management, is crucial. Through the practice of Kaizen, which is also known as continuous improvement. The practice of Kaizen requires the corporation from all individuals in case study industrial plant, from top administrators to front line operators. Continuous monitoring of process data generated by the aerosol production line during the improvement phase is required as teams seek to achieve optimum solutions implemented to improve the production line, develop and test action plans generated for implementation, controlled planning and validating long term capability of the production line. Kaizen is proven to bring effect of continuous improvement as published in various papers [18][11].

The case study industrial plant could also institutionalize the improvements through the amendment of systems and structures such as in recruitment, employee development programmes, incentives to provide motivation and encouragement for employees to work towards the improved the aerosol production line. Opportunities for further employees' development programme such as training should be provided to develop and ensure competency among employees at the aerosol line. Apart from that, recruitment of future employees such as competent operators and production engineers could place focus on maintaining and bringing improvements the production line. Key performance index, KPI is crucial as ensures employees focus on completing tasks and processes that are important to the success of the organization [19]. Incentives such as annual bonus salary could be provided to employees to that achieve the required key performance index, KPI to further encourage and motivate them.

V. CONCLUSION

In this research, the DMAIC approach was adopted to be used for this project to section the issues faced in the aerosol production line into different phases, ensuring a systematic method is used to improve the production line. The manufacturing process of aerosol grease was carefully observed and studied closely. Based on observations and data obtained, it was deduced that there are gaps for improvement and much improvements are to be made to improve the aerosol production line. The layout of the aerosol production line was found to be unoptimized, thus a new U- shaped layout that could reduce the distance travelled by operator in the production line by 22.26 % was proposed. It was also proposed that an additional operator is recruited and all operators at the production line should have improved flexibility in terms of machine operation. On top of that, the Kanban system was proposed to ensure inventories are managed more efficiently and to reduce transport and motion wastes. Apart from these, it was also proposed upgrades to some of their machines used in the production line to reduce over processing and queues. Lastly, 5S and Kaizen operation management tools that involved all employers was proposed to improve the performance of the aerosol production line, ensuring everyone in the case study industrial plant play a part to bring improvement towards the aerosol production line.

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REFERENCES

1. M. Sokovic, D. Pavletic and K. K. Pipan, "Quality Improvement Methodologies – PDCA Cycle, RADAR Matrix, DMAIC and DFSS," Journal of Achievements in Materials and Manufacturing Engineering, vol. 43, no. 1, pp. 478-483, 2010.
2. S. Sehgal and D. Kaushish, "A State of Art of Review of DMAIC Approach," International Journal of Science and Research (IJSR), vol. 8, no. 2, pp. 450- 452, 2015.
3. M. Smętkowska and B. Mrugalska, "Using Six Sigma DMAIC to improve the quality of the production process: a case study," Procedia - Social and Behavioral Sciences, vol. 238, p. 590 – 596, 2018.
4. Pavletić and M. Soković, "Six Sigma: A Complex Quality Inititative," Journal of Mechanical Engineering, vol. 48, no. 3, pp. 158-168, 2002.
5. J. Heizer and B. Render, Operations Management: Sustainability and Supply Chain Management, 11th ed., Pearson Education Limited, 2014.
6. T. Melton, "THE BENEFITS OF LEAN MANUFACTURING: What Lean Thinking has to Offer the Process Industries," Chemical Engineering Research and Design, p. 662–673, 2005.
7. A. Sihag, V. Kumar and U. Khod, "Application of Value Stream Mapping in Small Scale Industries," International Journal of Mechanical Engineering and Robotics Research, vol. 3, no. 3, pp. 738- 746, 2015.
8. G. Vinoth and S. Raghuraman, "Lean Engineering Principles: An Effective Way to Improve Performance and Process on Production Floow," International Journal of Mechanical Engineering and Robotics Research, vol. 2, no. 3, pp. 129- 136, 2013.
9. K. Venkataraman, B. V. Ramnath, V. M. Kumar and C. Elanchezhian, "Application of Value Streasm Mapping for Reduction of Cycle Time in a Machining Process," Procedia Materials Science, pp. 1187-1196, 2014.
10. H. Singh and A. Singh, "Application of Lean Manufacturing Using Value Stream Mapping in an Auto- parts Manufacturing Unit," Journal in Advances of Management Research, vol. 10, no. 1, pp. 72- 84, 2013.
11. W. A. Santosa and M. Sugarinda, "Implementation of Lean Manufacturing to Reduce Waste in Production Line with Value Stream Approach and Kaizen in Division Sanding Upright Piano, Case Study in: PT. X," in MATEC Web of Conferences, 2018.
12. S. Avikal, R. Jain, P. K. Mishra and H. C. Yadav, "A heuristic Approach for U- Shaped Assembly Line Balancing to Improve Labor Productivity," Computers & Industrial Engineering, vol. 64, no. 4, pp. 895- 901, 2013.
13. N. A. A. Rahman, S. M. Sharif and M. M. Esa, "Lean Manufacturing Case Study with Kanban System Implementation," in International Conference of Economics and Business Research 2013, 2013.
14. R. Almeanazel and O. Taisir, "Total Productive Maintenance Review and Overall Equipment Effectiveness Measurement," Jordan Journal of Mechanical and Industrial Engineering, vol. 4, no. 4, pp. 517- 522, 2010.
15. J. Singh, V. Rastogi and R. Sharma, "Total Productive Maintenance Review: A Case Study in Automobile Manufacturing Industry," International Journal of Current Engineering and Technology, pp. 2010-2016, 2013.
16. M. W. Wakjira and A. P. Singh, "Total Productive Maintenance: A Case Study in Manufacturing," Global Journal of researches in engineering, pp. 24-32, 2012.
17. M. N. A. Rahman, N. K. Khamis, R. M. Zain, B. M. Deros and W. H. W. Mahmood, "Implementation of 5S Practices in the Manufacturing Companies: A Case Study," American journal of Applied Sciences, vol. 7, no. 8, pp. 1182- 1189, 2010.
18. J.-. L. Cheng, "Integrating DMAIC With Kaizen Events Ensures Continuous Improvement," International Journal of Science and Research, vol. 6, no. 3, pp. 1154- 1156, 2015.
19. W. W. Eckerson, Creating Effective KPIs, New York: BizReport Trade Publications, 2006.

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