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Implementation of Root Cause Analysis (RCA) in painting process for Malaysian automotive industries

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KEYWORDS

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Industrial engineering
Painting

ABSTRACT

The shifting business between international and local private and public sectors, Malaysia's automobile industry has experienced economic growth. An additional development could be suggested and put into place to lessen the non-added values. For instance, flaws in the painting process are an issue for many makers of car parts. The most common ones are watermarking, blistering, solvent boil, chalking, wrinkling, spray dust, and dust contamination. Significant quality control tools including the Pareto diagram, check sheet, histogram, and cause-and-effect diagram are used to gather information and conduct analyses in order to remove flaws from the painting process. The competitiveness of the businesses may be significantly harmed by painting quality problems in the automotive sector. According to this viewpoint, in order to prevent difficulties in the future, corrective and preventive measures must be put in place in addition to identifying the root of the issue. The purpose of this study is to address the issue of defects in the painting process by adopting Root Cause Analysis (RCA) in lean manufacturing. The results of RCA and Pareto analysis indicate that the first two causes account for 86.5% of all problems. According to the 80:20 rule, just 20% of the causes are responsible for the majority (80%) of the issues. In conclusion, Lean manufacturing must therefore be used in order to assist and advance Malaysia's automotive industry's efforts to improve product quality.

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1.0 INTRODUCTION

One of the disciplines that works to improve processes, save the organisation money, and maintain competitiveness is industrial engineering. Analysing tasks or processes to boost productivity and quality is one of the key activities in industrial engineering [[2], [3]]. It is well accepted that using effective problem-solving methods and high-quality tools and approaches together is necessary to comprehend any process and enable improvement [[1], [3], [31], [32]].

Wastes are anything that adds no further value to the process. There are two main categories of waste: hidden waste and obvious waste. Hidden is necessary under the current operating procedures, such as excessive overtime and surplus labour, can be reduced or even eliminated by upgrading the procedures. While obvious waste, such as flaws, delays, excess manufacturing, transportation, inventory, complexity, and untapped innovation, is simple to spot [[1], [33]]. These wastes will raise the price, degrade the quality, and prevent conformance with client requirements. The typical rejection and rework rate should be between 3% and 5% [2].

If the cost is higher, the company's efficiency will suffer because they will only generate a smaller profit. One of the frequent factors driving up costs in the automobile sector is waste. Waste that adds no value merely creates more effort. Therefore, it is necessary to get rid of the garbage. A change must be made to raise process quality while lowering production costs in order to achieve this. Industrial engineering is an appropriate profession to use industrial engineering methods to increase quality and reduce costs [[1], [34], [35]].

The value of lean manufacturing has been the subject of some research, particularly the challenges it presents. Value stream mapping, overprocessing, and inventory problems have all been thoroughly examined [[1], [2], [4], [5], [6], [7]]. However, there aren't many studies that concentrate on the most frequent issues with flawlessly created car parts, particularly during the painting process. This necessitates making certain changes to the painting procedure. Stabiliser bars are manufactured using nine fundamental procedures in the automotive components business. The bending stage of the process is when it all begins. Figure 1 depicts these fundamental steps in the process. Only the painting procedure will be examined in this study. The company will choose whether to execute the change or not due to cost and time constraints. Some improvements will be suggested to address the defect problem.

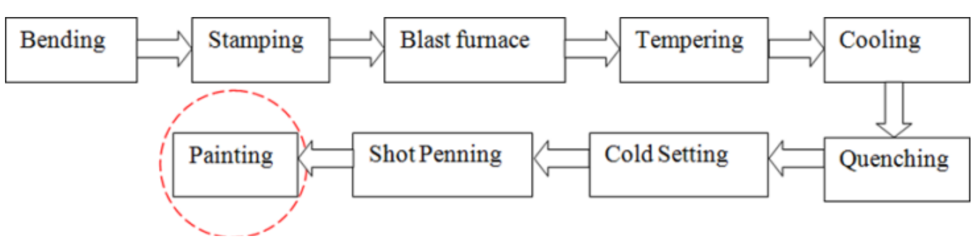

Figure 1: Basic step in manufacturing stabilizer bar

Lean manufacturing and root cause analysis (RCA) are tools used to pinpoint issues and determine their reasons. By combining these techniques, a complete approach to problem solving may be offered, one that includes both problem identification and the recommendation of appropriate solutions in the automotive industry.

1.1 Lean Manufacturing

Lean manufacturing uses the perspective of the consumer to describe the value of a product or service. Customers do not care how much labour or technology was utilised to produce the good or service that is for sale [4]. How well something will meet their needs will be used by customers to evaluate the goods or services. Customers do not have to pay for the high overhead costs associated with the facility or for the quality flaws that were eliminated from the production lines [[3], [5], [29]]. With the product or service that is offered, customers will pay for the fulfilment of the requirements [4, 13].

According to the Lean Manufacturing principle, high-quality products should be less expensive to produce because doing so will result in lower costs than producing low-quality products [[2], [4], [7]]. This is because higher costs are associated with maintaining quality controls, rejecting parts, and replacing damaged products.

Today's markets, however, distinguish between the higher grade products and the lesser quality ones. The production process does not incorporate quality. Among products of ordinary or poor quality, quality products are preferred. It follows that the value will be defined differently by customers than by the manufacturer. How much the product or service is worth to the maker does not really matter. According to lean manufacturing, it is crucial to understand exactly what constitutes a waste [[2], [8], [30]].

Anything that does not add value to the finished product is referred to as a waste in lean manufacturing. It is entirely reasonable to define waste in this way if the client recognises the value in the finished product. Wastes that can be prevented exist. First, identify the waste and classify it as preventable or unavoidable. Next, following the fundamentals of lean manufacturing, try to eliminate the waste rather than just reduce it [[3[, [5], [28]].

The meanings of these two words are significantly dissimilar. There are varied quantities of wastes in the system when wastes are minimised. However, eliminating waste from the system is a key lean manufacturing principle [[2], [4], [7], [11], [12], [16], [17], [27]]. Solutions for lean manufacturing are frequently quite straightforward and very efficient. People that can think differently or creatively are needed for this type of problem-solving since creative thinking has the power to entirely alter the reality.

Every action, according to lean manufacturing, is connected to the system as a whole. Improvement in one activity will therefore boost the system as a whole. So every time, the process of identifying waste and its precise sources, conducting research and studies to eliminate the waste, and putting lean into practise would rotate. Up until there are wastes that need to be eliminated, this process will continue [[2], [6], [14], [15], [18], [25], [26]].

The purpose of this study is to apply lean manufacturing by identifying potential causes and evaluating potential remedies for the primary issue in the painting process. The appropriate company will be contacted for any pertinent information. The Root Cause Analysis (RCA) must then be used to examine and analyse the data.

2.0 METHODOLOGY

The problem identification methodology uses a variety of types and techniques. The approaches include giving questionnaires, observing the current procedure, and researching corporate records. Through the painting production line, led by the designated line leader, observations of the ongoing process have been made. The finding that occurs while the product continues to function without pausing the operation. The most common problems in painting process are watermarking, blistering, solvent boil, chalking, wrinkling, spray dust, and dust contamination. This is being done to see if there's any chance that a production issue might arise. Additionally, the maintenance, quality, and manufacturing departments have each received a questionnaire. This is an investigation on the common issues.

The machine, material, method, manpower, and fault will be the primary factors that will be examined in this project. The company's paperwork has been evaluated in order to learn more about the present state of the business and to identify the major issues that might have an impact on how well the company performs. Problem identification must be done early on if the problem is to be solved. This is crucial so that suggestions can be made to enhance the current production process and boost business productivity [[22], [23], [24], [36]]. The deficiencies in the finished goods are one of the primary issues that have an impact on the firm's performance, according to the observation, questionnaire, and documentation study that was conducted on the company. Five categories namely machine, material, technique, workforce, and defect are used to categorise the issue.

These are the areas where issues could arise and where large prices are present. This flaw might have an impact on both the production lines' effectiveness and the quality of the stabiliser bar itself. Due to the high incidence of rejection and rework, the defect problem could raise the cost. Typically, difficulties with the raw material are vendor-related. According to the data gathered, there could be a wide range of factors for the high cost.

2.1 Root Cause Analysis

Industrial engineering, which focuses on the analysis and design of work, is necessary to increase productivity and performance. The goal of industrial engineering is to use industrial engineering tools to increase productivity and quality in order to assist the organisation perform better and save money [2, 5]. Companies have used a variety of techniques to raise their quality over time.

The Root Cause Analysis (RCA) is a common methodology that is straightforward and simple to apply. RCA is a technique for solving problems that seeks to pinpoint the root causes of an issue. There are seven problems with the painting's defects were studied. The most common ones include dust contamination, chalking, wrinkling, solvent boil, blistering, and spray dust. While irregular coating thickness, contaminants, and issues with oven temperature are additional factors that lead to these seven flaws. The goal of RCA is to locate the probable source of an issue utilising a set of steps and techniques in order to provide answers to questions regarding the what, why, and how of problems as well as what can be done to lessen the risk that they will occur again. In RCA, there are often five specific phases [[9], [10], [19], [20], [21]].

Phase 1: Defining Step

In this stage, the issue is identified. Typically, the problem occurs before it can be defined. Based on the initial assessment of the issue, the question must be addressed. What do you see happening, exactly, could be the problem. While the query of what specific symptoms there are could provide a basic sense of the causes of the issue.

Phase 2: Data Collection

The next step is to gather data gathering. This is due to the fact that the existence of the issue must be established. It is also necessary to determine how long the issue has existed and what effect it is having. The data gathering process may provide the solution to the second RCA step's inquiry. Additionally, by gathering data, the RCA might be used to examine the same scenario from a variety of angles, maximising its usefulness.

Phase 3: Identify the Possible Factors

The most number of potential causes must be determined at this stage. These processes might be aided by asking questions such what series of events results in the problem, what circumstances permit the problem to occur, and what secondary problems surround the main problem.

Phase 4: Identify The Root Causes

Finding the core causes can aid in determining why the casual element exists and what the true cause of the issue was.

Phase 5 Recommend and Implement Solutions

After thoroughly examining the fundamental problem, a solution ought to be suggested and put into practise. It is possible to determine which systems require adjustments. To plan the action taken, it is important to find out the answers to questions such what can be done to stop the problem from happening again, how the solution will be implemented, who will be responsible for it, and what risks there are in doing so.

3.0 RESULTS AND DISCUSSION

The flaws in the painting process are displayed in Table 1. There are seven issues with how the painting was done. Watermarking, blistering, solvent boil, chalking, wrinkling, spray dust, and dust contamination are the most typical. Each of these flaws could aggravate the quality issue. In order to analyse the highly common problem and the likelihood that it will occur again, a collection of data was gathered. The Pareto chart in Figure 2 is used to analyse the data in the manner described below. According to Table 1, which is based on the Pareto chart, the first two causes account for 86.5% of all defects. Following the 80:20 rule means that just a tiny portion (20%) of the causes are responsible for the majority (80%) of the problems.

The faults in the painting process are discovered to be caused by seven issues. According to our analysis, contaminants, uneven coating thickness, and an oven temperature issue are the primary sources of issues. The Ishikawa diagram has been used to depict all contributing components and their link to the result in order to determine the causes and effects of each problem. Finally, a number of factors will be found to be the primary causes of the issue.

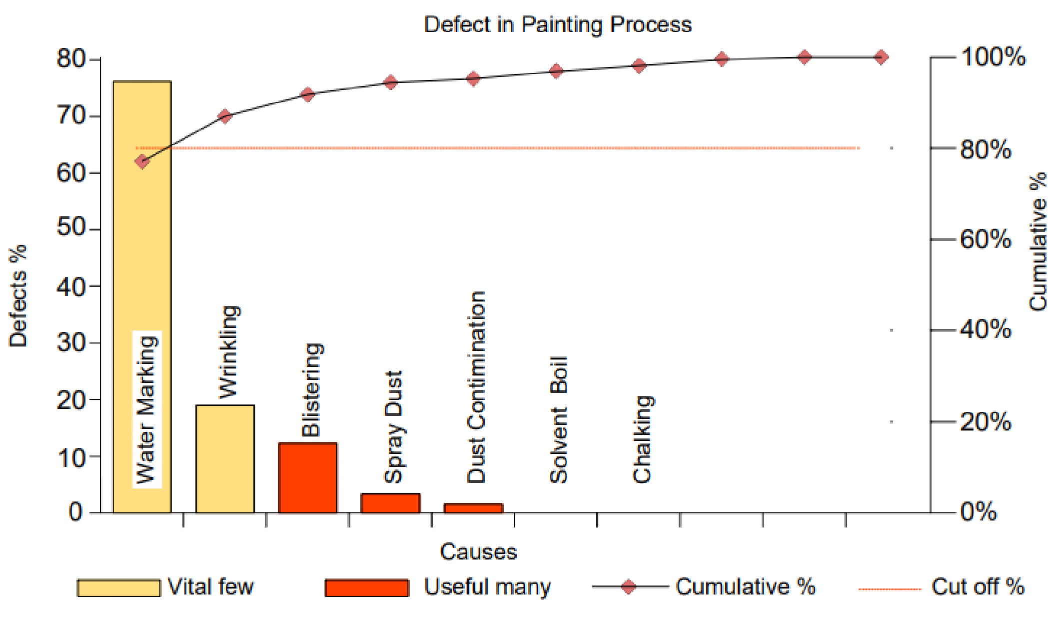

Figure 2: Problems contributed to defects

Table 1: Analysis of defects in painting process

	Cumulative Percentage Cutoff:	80%
Defects	**Defects %**	**Cumulative %**
Water marking	75	75.0
Wrinkling	11.5	86.5
Blistering	8	94.5
Spray dust	2.5	97.0
Dust Contimination	2	99.0
Solvent boil	0.5	99.5
chalking	0.5	100.0

3.1 Oven temperature problems

They recently discovered an issue with the oven's temperature. The temperature board or clock takes a while to beep and achieve the preset. Sometimes, the burners are not operated precisely. Therefore, the Ishikawa diagram has been used to brainstorm all the causes in Fig. 3 and the five why analysis is displayed in Table 2 in order to discover the reasons of the problem. The method is by far the most frequent cause of the oven temperature issue, according to the interview and process observation. The 5 Why analysis have been used to identify the causes.

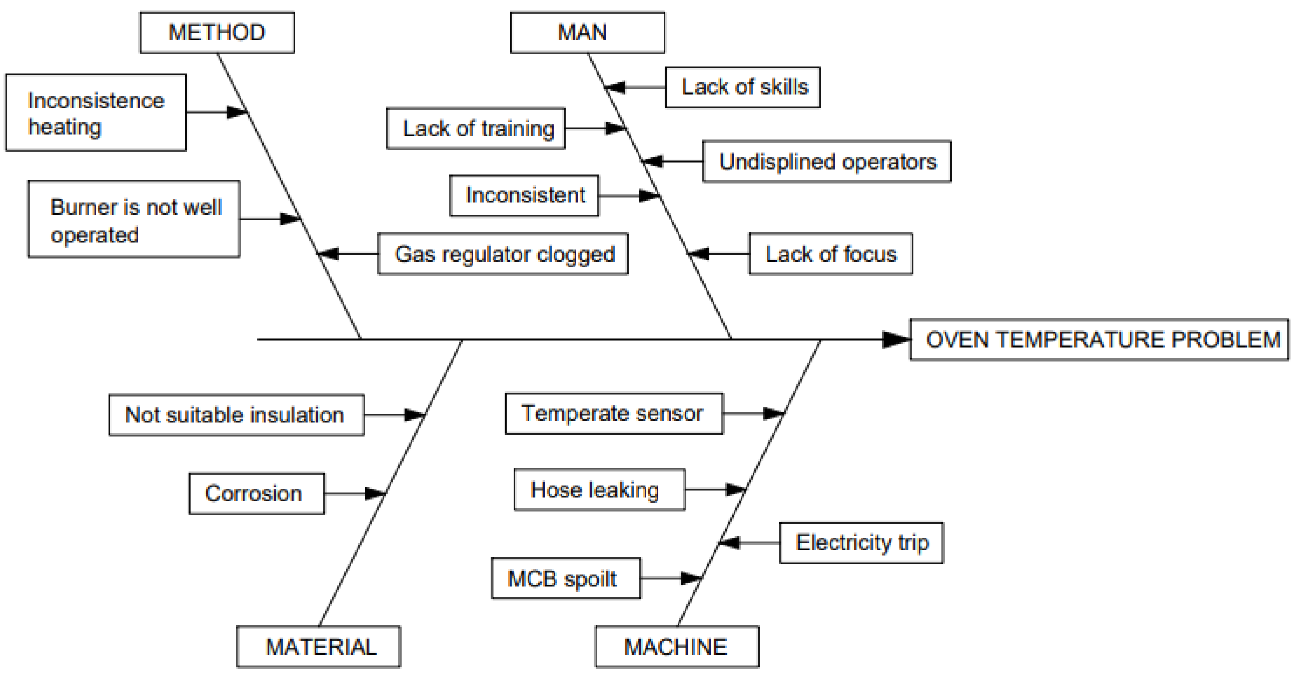

Figure 3: Oven Temperature problem

Table 2: Why of oven temperature problems

5 WHY	Description
WHY 1	Burner is not working properly
WHY 2	Filter clogged
WHY 3	Nozzle flame burner clogged
WHY 4	Gas regulator clogged

This occurs when anything has an impure quality or state, particularly when it is contaminated or polluted. Due to inconsistent management of the material, it typically happens during the process. Lack of knowledge on the use of lint-free dungarees and clothing is another issue. Additionally, the booth must be subject to routine maintenance, including filter changes. In addition, it is important to make sure that polishing or finishing areas are set apart from the paint shop by filtered and ventilated systems. The Ishikawa diagram of impurities is shown in Figure 4. 5 Why are evaluated in Table 3. The method and material are by far the most frequent causes of the conveyor issue, according to the interview and process observation. Below is an example of a 5 Why analysis used to identify the causes.

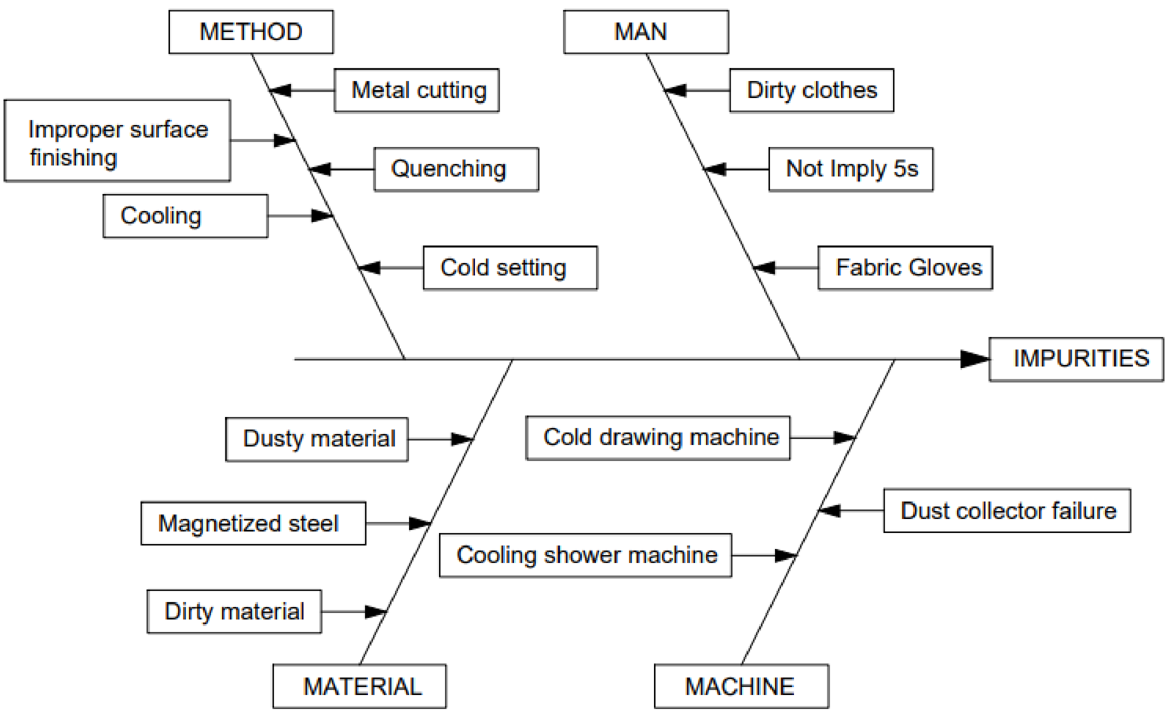

Figure 4: Impurities problem

Table 3: Why of impurities problem

5 WHY	Description
WHY 1	Did not use leaather/rubber gloves
WHY 2	Pre-treatment shower did not properly cleaned the product
WHY 3	Nozzle shower clogged
WHY 4	Low specification of chemical from pre-treatment

3.2 Uneven coating thickness

An essential element of product quality, process control, and cost management is coating thickness. Uneven coating thickness can result from a variety of factors, including poor surface preparation, poor coating selection, poor application, inappropriate drying, improper curing and overcoating durations, and mechanical damage. The Ishikawa diagram in Figure 5 and the five reasons analysis in Table 4 both illustrate the reasons for uneven coating thickness problems.

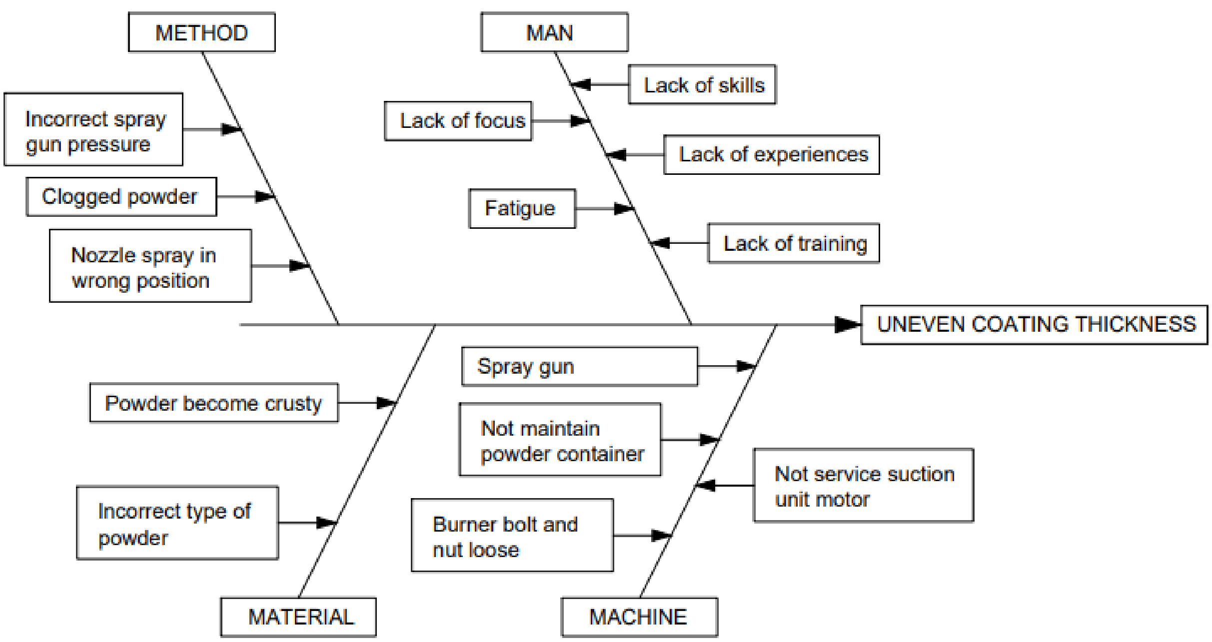

Figure 5: Uneven coating thickness problem

Table 4: Why of uneven coating thickness analysis

5 WHY	Description
WHY 1	Low air pressure of the nozzle
WHY 2	Operator did not following the standard operation procedure (SOP)
WHY 3	Power gun or injector clogged

4.0 CONCLUSIONS

Due to Malaysia's automotive industry's rapid development, an automobile parts manufacturer was chosen for this study. This study involved the application of painting to the creation of automotive parts. Five categories: machine, technique, man, material, and defect are in which issues may arise. The contaminants, uneven coating thickness, and an oven temperature issue are the primary sources of issues due to the most prevalent issue mentioned in the survey, multiple defective issues have been detected in this situation. Based on the results of RCA and Pareto analysis, the first two causes account for 86.5% of all defects. According to the 80:20 rule, the bulk (80%) of the issues are caused by a small percentage (20%) of the causes. It is found that there are seven problems that lead to the painting process's flaws. Based on the investigation, the primary factors contributing to painting problems are impurities, uneven coating thickness, and oven temperature. Due to this, all pertinent data was gathered and put through Root Cause Analysis (RCA), Pareto analysis, and other high-quality techniques of analysis to pinpoint remedial measures that could boost business productivity and aid in waste reduction. In general, it must be obvious that any non-conformities must be resolved gradually and methodically, using the right instruments or a mix of approaches, in order to ensure that the non-conformity is recognised and that the necessary steps are done to prevent occurrence. In the future, managers will be able to use a scientific approach to quality assurance and the creation of high-quality goods at affordable prices provided proper procedures and techniques are applied for monitoring and quality control during the painting process.

Author Contribution

A. Mohd and W.A.Y. Yusoff: Conceptualization, methodology, investigation, visualisation, writing and editing. A. Mohd: Analyzing, writing and editing. Attia Boudjemline and Naim Ben Ali: Investigation, supervision, writing, and editing.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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5.0 REFERENCES

[1] Putri, Nilda Tri and Yusof, S.M. Critical Success Factor Implementing Quality Engineering Tools and Technique in Malaysian and Indonesian Automotive Industries. Proceedings of the IMCES ,2009 , Hong Kong.

[2] Juthamas Choomlucksana, Monsiri Ongsaranakorn, Phrompong Suksabai Improving the Productivity of Sheet Metal Stamping Subassembly Area Using the Application of Lean Manufacturing Principles Procedia Manufacturing, Vol. 2, 2015, Pages 102-107

[3] W.Widiasih, Putu Dana Karningsih, Udisubakti Ciptomulyono Development of Integrated Model for Managing Risk in Lean Manufacturing Implementation: A Case Study in an Indonesian Manufacturing Company Procedia Manufacturing, Vol. 4, 2015, Pages 282-290

[4] S. Singh Aulakh & Janpreet Singh Gill. Lean Manufacturing- A Practitioner's Perspective. IEEE,ICIEEM, 2008, Pages75 – 79.

[5] P. Chiabert, G. D'Antonio, J. Inoyatkhodjaev, F. Lombardi, S. Ruffa Improvement of Powertrain Mechatronic Systems for Lean Automotive Manufacturing Procedia CIRP, Volume 33, 2015, Pages 53-58.

[6] Yu Cheng Wong, Kuan Yew Wong & Anwar Ali. Key Practice Area of Lean Manufacturing, IEEE Xplore International Association of Computer Science and Information Technology, Singapore, 2009, Pages 57 – 61.

[7] A. Fercoq, S. Lamouri, V. Carbone, A. Lelièvre, A.A. Lemieux Combining lean and green in manufacturing: a model of waste management, IFAC Proceedings Vol 46, Issue 9, 2013, Pages 117-122.

[8] Weixing Su, Lianbo Ma, Kunyuan Hu & Lei Zhang. A Research on Integrated Application of RFID-based Lean Manufacturing. IEEE Xplore Int. Conf.e: Control and Decision Conference 2009, China.

[9] Avishek Pal, Pasquale Franciosa, Darek Ceglarek. Root Cause Analysis of Product Service Failures in Design-A Closed-loop Lifecycle Modelling Approach, Procedia CIRP,Vol. 21, 2014, Pages 165-170.

[10] S. Volker, G.Prostean Research of Automotive Change Management and Combined Risk- Mgt Models Procedia - Social and Behavioral Sciences, Vol.221, 2016, Pages 395-404.

[11] C Botezatu, I Condrea, B Oroian, A Hriţuc, M Eţcu1and L Slătineanu. Use of the Ishikawa diagram in the investigation of some industrial processes, IOP Conference Series: Materials Science and Engineering, Volume 682, 10th International Conference on Advanced Manufacturing Technologies 10–11 October 2019, Bucharest, Romania, IOP Conf. Ser.: Mater. Sci. Eng. 682 012012.

[12] Andrzej Pacana and Dominika Siwiec, Universal Model to Support the Quality Improvement of Industrial Products, Materials 2021, 14(24), 7872.

[13] Anna Nagyová, Hana Pačaiová, Anna Gobanová, Renáta Turisová. An Empirical Study of Root-Cause Analysis in Automotive Supplier Organisation, Quality Innovation Prosperity/Kvalita Inovácia Prosperita 23/2 – 2019.

[14] P S Roy, M S Rabbi, S C Banik and M M Rahman, Investigation of Production Line Defects Using Root Cause Analysis: A Case Study on An Automobile Industry In Bangladesh, International Journal of Management (IJM) Volume 12, Issue 2, February 2021, pp.713-719.

[15] S. Papadopoulou, A. Vazdirvanidis, A. Toulfatzis, A. Rikos, and G. Pantazopoulos, Failure Investigation of Products and Components in Metal Forming Industry: Root Cause Analysis and Process-Based Approach, Journal of Failure Analysis and Prevention, 20(1), 2020, 106-114.

[16] P. Kumari, D. Lee, Q. Wang, M. N. Karim, and J. S. I. Kwon, Root cause analysis of key process variable deviation for rare events in the chemical process industry, Industrial & Engineering Chemistry Research, 59(23), 2020, 10987-10999.

[17] Chia-Fen Chi, Davin Sigmund and Martin Octavianus Astardi, Classification Scheme for Root Cause and Failure Modes and Effects Analysis (FMEA) of Passenger Vehicle Recalls, Reliability Engineering & System Safety Volume 200, August 2020, 106929.

[18] Zhaoguang Xu and Yanzhong Dang, Data-driven causal knowledge graph construction for root cause analysis in quality problem solving, International Journal of Production Research Volume 61, 2023 - Issue 10, 3227-3245.

[19] Dominik Rotter, Florian Liebgott, Daniel Kessler, Annika Liebgott and Bin Yang, Machine Learning-Based Identification of Root Causes for Defective Units in Manufacturing Processes, SCAP 2022: Advances in Automotive Production Technology – Towards Software-Defined Manufacturing and Resilient Supply Chains, 2023, 168–178.

[20] Abdelrahman, O., Keikhosrokiani, P.: Assembly line anomaly detection and root cause analysis using machine learning. IEEE Access 8, 189,661–189,672 (2020).

[21] Carletti, M., Masiero, C., Beghi, A., Susto, G.A.: Explainable machine learning in industry 4.0: evaluating feature importance in anomaly detection to enable root cause analysis. In: 2019 IEEE SMC, pp. 21–26 (2019).

[22] Y. Pan, W. Dai and Y. Xiong, "Investigation on the Material Failure in a Small Scale Automotive Camera Module via Root Cause Analysis and Experimental Validation," in IEEE Access, vol. 7, pp. 72818-72825, 2019.

[23] e Oliveira E, Miguéis VL, Borges JL. Overlap in Automatic Root Cause Analysis in Manufacturing: An Information Theory-Based Approach. Applied Sciences. 2023; 13(6):3416.

[24] Shiau, Y.R.; Wang, S.Y. Key improvement decision analysis mechanism based on overall loss of a production system. J. Ind. Prod. Eng. 2021, 38, 66–73.

[25] Tan, C.M.; Chen, H.H.; Wu, J.P.; Sangwan, V.; Tsai, K.Y.; Huang, W.C. Root Cause Analysis of a Printed Circuit Board (PCB) Failure in a Public Transport Communication System. Appl. Sci. 2022, 12, 640.
[26] Papacharalampopoulos, A., Giannoulis, C., Stavropoulos, P. and Mourtzis, D., A digital twin for automated root-cause search of production alarms based on KPIs aggregated from IoT. Appl. Sci. 2020, 10, 2377.
[27] Xu, Z. and Dang, Y., Automated digital cause-and-effect diagrams to assist causal analysis in problem-solving: A data-driven approach. Int. J. Prod. Res. 2020, 58, 5359–5379.
[28] e Oliveira, E., Miguéis, V.L. and Borges, J.L., Understanding Overlap in Automatic Root Cause Analysis in Manufacturing Using Causal Inference. IEEE Access 2022, 10, 191–201.
[29] Detzner, A.; Eigner, M. Feature selection methods for root-cause analysis among top-level product attributes. Qual. Reliab. Eng. Int. 2021, 37, 335–351.
[30] Konstantinos Papageorgiou, Theodosios Theodosiou, Aikaterini Rapti, Elpiniki I. Papageorgiou, Nikolaos Dimitriou, Dimitrios Tzovaras and George Margetis, A systematic review on machine learning methods for root cause analysis towards zero-defect manufacturing, Front. Manuf. Technol., 28 October 2022, Sec. Life Cycle Engineering, Volume 2 – 2022.
[31] Martin-Delgado J, Martínez-García A, Aranaz JM, Valencia-Martín JL, Mira JJ., How Much of Root Cause Analysis Translates into Improved Patient Safety: A Systematic Review, Med Princ Pract. 2020;29(6):524-531.
[32] Shamsu Anuar, M. A., & Mansor, M. A., Application of value stream mapping in the automotive industry: a case study, Journal of Modern Manufacturing Systems and Technology, 6(2) (2022), 34–41.
[33] Fuller, H. J. A., Arnold, T., & Bagian, T. M., Learning from root cause analysis (RCA) actions that use standardization to address patient safety concerns, Proceedings of the International Symposium on Human Factors and Ergonomics in Health Care, (2021), 10(1), 281-285.
[34] Keyser, R. S., Lean at Home: Applying RCA Techniques to Home Projects, J. Appl. Res. Ind. Eng. Vol. 8, No. 2 (2021) 104–115, E-ISSN: 2676-6167 | P-ISSN: 2538-5100.
[35] Aized, T., Ahmad, M., Jamal, M. H., Mahmood, A., Ubaid ur Rehman, S., & Srai, J. S., Automotive leaf spring design and manufacturing process improvement using failure mode and effects analysis (FMEA). International journal of engineering business management (2020), 12, 1-13.
[36] Jasti, N.V.K., Kota, S. and Sangwan, K.S., An application of value stream mapping in auto-ancillary industry: a case study, The TQM Journal (2020), Vol. 32 No. 1, pp. 162-182.