JURNAL TEKNIK

Volume 21, No. 2, Desember 2023
P-ISSN : 1693-6191 E-ISSN : 2715-7660 DOI : https://doi.org/10.37031/jt.v21i2.342

Implementation of DMAIC for Production Quality Control: Case Study of Power Supply Production in Indonesia

[1]B. Handoko Purwojatmiko, [2]Laksmi Ambarwati

[1,2] Automotive Industrial Engineering, Politeknik STMI Jakarta, Jl. Letjend Suprapto No.26 Jakarta Timur 10510, Indonesia
e-mail: bhandoko@stmi.ac.id

Abstrak

Tingkat persaingan industri manufaktur yang semakin ketat membuat perusahaan harus mampu memberikan pelayanan terbaik kepada pelanggan. Salah satu perusahaan di Indonesia yang bergerak pada bidang pemantauan aset dan sistem navigasi kapal, memiliki divisi produksi yang menghasilkan produk catu daya (*power supply*). Berdasarkan analisis yang telah dilakukan pada perusahaan tersebut terdapat permasalahan seperti adanya PCB konektor yang rusak sehingga membuat produk dikategorikan menjadi cacat produksi. Penelitian ini memiliki tujuan untuk dapat menemukan alternatif perbaikan terhadap proses produksi yang memiliki tingkat cacat tinggi. Adapun kerangka *Define, Measure, Analyze, Improve,* dan Control (DMAIC) digunakan sebagai metode untuk membentuk pola pikir manajemen dan karyawan untuk dapat menyelesaikan permasalahan tersebut. Berdasarkan kerangka tersebut ditemukan tiga penyebab permasalahan yaitu faktor manusia, material dan metode yang kurang tepat saat proses produksi. Oleh karena itu dilakukan tindakan perbaikan yang sesuai dan dilakukan proses kontrol dengan membandingkan peta kendali, *Defect Per Million* Opportunities (DPMO) dan level sigma untuk mengetahui dampak perubahan dari perbaikan yang dibuat. Secara kuantitatif terdapat peningkatan nilai DPMO sebesar 39,47% dan peningkatan level sigma mencapai 8,64%. Hal ini menunjukkan bahwa kerangka berpikir DMAIC mampu untuk memberikan solusi yang tepat dan juga mencegah permasalahan kualitas yang sama terjadi kembali.

Kata kunci: DMAIC, Pengendalian Kualitas, DPMO, Level Sigma

Abstract

The level of competition in the manufacturing industry is getting tougher, making companies must be able to provide the best service to customers. One of the companies in Indonesia engaged in asset monitoring and ship navigation systems, has a production division that produces power supply products. Based on the analysis that has been carried out at the company that there are problems such as a damaged PCB connector that makes the product categorized as a manufacturing defect. This research aims to be able to find alternative improvements to production processes that have a high defect rate. The Define, Measure, Analyze, Improve, and Control (DMAIC) framework is used as a method to shape the mindset of management and employees to be able to solve these problems. Based on this framework, three causes of the problem were found, namely human factors, materials, and inappropriate methods during the production process. Therefore, appropriate corrective actions are taken, and a control process is carried out by comparing control charts, Defects Per Million Opportunities (DPMO) and sigma levels to determine the impact of changes from the improvements made. Quantitatively, there was an increase in the DPMO value of 39.47% and an increase in the sigma level of 8.64%. This shows that the DMAIC framework can provide the right solutions and preventing the same quality problems from happening again.

Keywords: *DMAIC, Quality Control, DPMO, Level Sigma*

Diterima:
Disetujui: 13 Desember 2023
Dipublikasi: 31 Desember 2023

Introduction

The level of industrial competition in the globalization era encourages company owners and leaders to be able to determine the success of their business through quality improvement. Quality improvement is not only seen from how the products produced can meet the criteria, but also how the form of service to the internal and external of a company. Quality control is no longer a new thing, but is the most important thing in producing products and services. Continuous improvement is also an important matter of concern, so that the level of quality control can increase and conditions in the era of globalization and after the Covid-19 pandemic. Quality control is an activity carried out to obtain a quality parameter by comparing product specifications with actual products made with the aim of finding out gaps or things that are not in accordance with predetermined standards (Ai et al., 2021). Reduction of production defects is one of the problems that is almost faced by various types of industries. If these problems are not handled properly, it will cause losses to the company (Powell et al., 2022).

In general, a company already has a quality control system that can help production not to produce excess production defects. One of the multinational companies operating in Indonesia and engaged in asset monitoring and ship tracking communication navigation systems has a power supply production line. The production of this power supply will then be used as an object in this research. The power supply produced is used as a supporting component in the ship's navigation system. In the power supply production process, several supporting components are needed such as printed circuit boards (PCB), connecting cables, current connectors and other electronic components that are assembled in one system. In the process of assembling this power supply, some of the biggest problems were found where during PCB installation, installation errors were found which could result in the PCB being damaged or a short circuit occurring. The damage to the PCB will result in the power supply not being able to operate optimally and not even being used according to the application. Therefore, it is necessary to evaluate the procedures for the PCB installation process in order to prevent these problems from reaching the customer.

The purpose of this research is to solve the problems in the PCB installation process using a data-based approach to be able to provide gradual improvements using the Define, Measure, Analyze, Improve, Control (DMAIC) principle (Kumar Phanden et al., 2022). The DMAIC framework can be used as a solution to solving quality problems that can be implemented in companies. The data required in the DMAIC framework comes from the many levels of defects during the production process and after the final inspection before the product reaches the customer. The DMAIC framework used in this problem is intended to ensure or prevent missed process sequences and is expected to improve the quality of existing processes (Samuel et al., 2021). In addition, the DMAIC framework will also be able to minimize the level of defects in the production line.

In addition, quantitative data comparisons are also needed to test whether there are significant changes after the improvement process. Defect per Million Opportunity (DPMO) is used in quantitative analysis where DPMO is part of six sigma which is an approach to changing organizational culture (Deeb et al., 2018). The sigma level is then determined based on the conversion of the DPMO value which is used to determine the sigma level of a company. The higher the sigma level will represent the quality of the performance of a company.

Methodology

The DMAIC framework is used as a guide in improving production processes (Kumar Phanden et al., 2022). The defects data collected is production data in August 2022. The initial stage is defining the problem by determining the improvement position. In this initial step, it is necessary to specifically determine customer needs by collecting voice of customers (VoC) through interviews with management and company employees (Shen et al., 2022). The purpose of the VoC is to ensure that all problems have been collected for further analysis. Next is to make a Supplier, Input, Process, Output, Customer (SIPOC) diagram to see the relationship between problems and their impacts. The second stage is measuring which problems have critical to quality (CTQ) criteria, one of which is by using Pareto charts and control charts (Pacana et al., 2021).

The third stage is analyzing the problem to find the root cause of the problem by using a fishbone diagram. At this stage it will be seen from several factors such as man, method, and material which can affect the high defect PCB connector. After getting the core of the problem from this stage, then proceed to the next stage. The fourth stage is improvements related to determining solutions to the problems described in the fishbone diagram. The 5W+1H analysis is used to get answers to each predetermined problem by brainstorming with relevant stakeholders. The final stage is controlling the results of the improvement. The way to control is to make a comparison between before and after the repair by looking at the control chart and calculating the DPMO and the sigma level. In making the control chart, the value of the proportion of defective products is determined in advance based on the data that has been collected.

Results and Discussion

Results

The results of this research are expected to provide impetus for companies to be able to make significant improvements based on the data collected correctly. The DMAIC framework can make it easier for companies, especially management, to form a continuous improvement mindset (Müller et al., 2020). In the early stages, defining quality problems that occur in the power supply production process must be done by knowing the stages of the process. The stages of the process are component selection, PCB connector installation, component inspection, PCB assembly on the power supply, and final inspection on the power supply before the product is stored. The Suppliers, Input, Process, Outputs, Customers (SIPOC) diagram is used to map the repair positions shown in Figure 1.

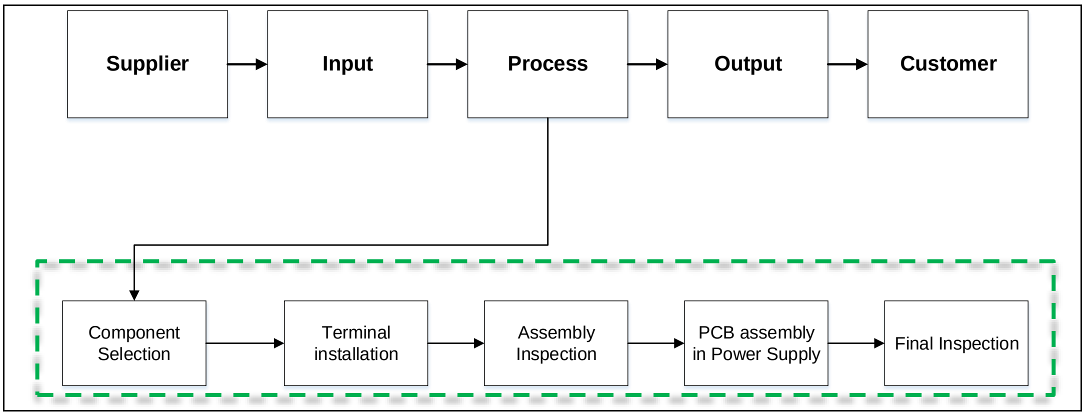

Figure 1. SIPOC Diagram of Power Supply Manufacturing Process

The first data collection stage is data on the number of production and the number of defects. The data collected is data for August 2022. The average production volume in one day is 44 units and the average production defect unit is 5 units in one day with the total production is 1112 unit. Based on the data, the defective product is then categorized into three types of defects in the production of the power supply assembly. The collected data was shown as a pareto diagram in figure 2.

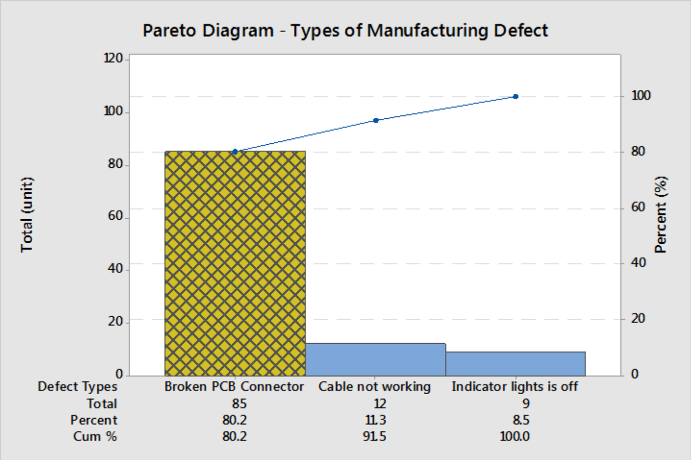

Figure 2. Pareto diagram of types of manufacturing defect

Based on Figure 2, it was found that the damaged PCB connector became a type of defect that had the highest frequency compared to other types of defects. Damaged PCB connector has a defective percentage of 80.2%, the cable does not work by 11.3% and the indicator light is off by 8.5%. Priority for solving the problem will be focused on the type of defect PCB connector is damaged. This is consistent with the results obtained from the VoC where the interview results show the company's desire to produce products with low defects. The control chart is then used to analyze the output of the production process. This study uses a p control chart to determine the proportion of defects from a collection of product items during the inspection process (Park et al., 2021). The proportion of the number of defective products can be determined through the equation of the number of defects per period divided by the number of productions per period (Godina et al., 2018). Next, calculate the central line (CL), upper control limit (UCL), lower control limit (LCL) values to be able to describe the control chart for the type of defective PCB connector before and after improvement as shown in Figure 3. Based on the control chart, it was found that their fluctuations in the number of defects within a certain period which will have an impact on production capacity.

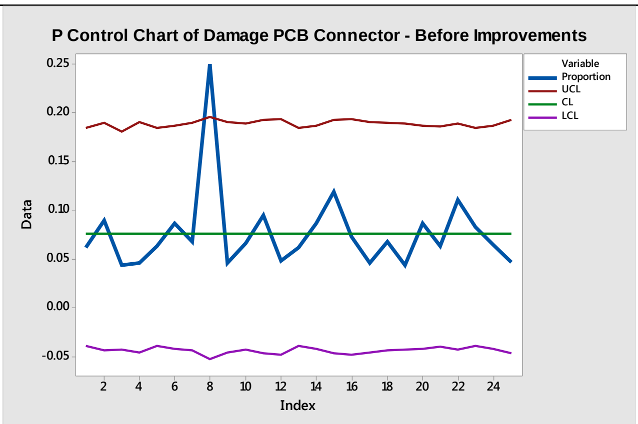

Figure 3. P-Control chart for damage PCB connector before improvements

After the measurements, the analysis stage is carried out based on the previous data. It is known that there is one type of defect that has a high frequency of occurrence, namely a damage PCB connector. At this stage, the root causes of the problems that have been determined in the previous stage will be sought using tools such as fishbone diagrams (Luo et al., 2018). This is done to find out exactly the main root cause of the problem and be able to estimate the right recommendations to solve the problem. The fishbone diagram can be seen in Figure 4 where the construction is based on interview results. The problem can be mapped from the production process of the power supply assembly. In the fishbone diagram, there are three factors that cause PCB connector problems, including man, material, and method. The diagram shows that there is still unstable operator performance where they are in a hurry to carry out the process but without paying attention to what components will be installed. For material factors, there were findings that there were components that did not have a special label according to the assembly production line at that time and did not have verification process. This is what triggers the emergence of component installation errors, causing the production of power supply assembly to be disrupted. The third factor is the method where the placement of components in the production area is not neatly arranged, thus affecting the sequence of the process of assembling the connector components.

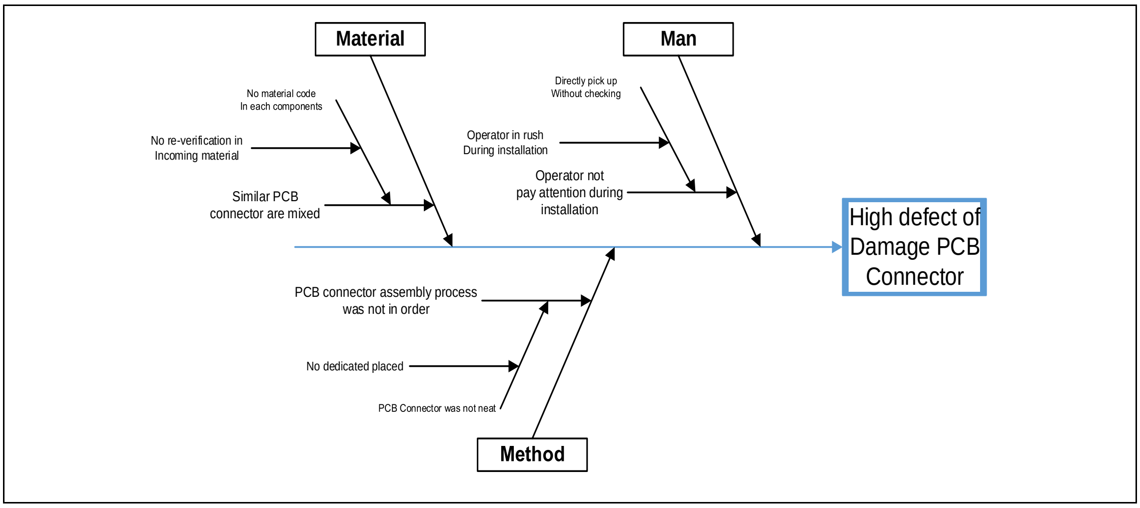

Figure 4. Fishbone Diagram for damage PCB connector

The fourth stage is the improvement stage of the problem analysis that has been done before. The activities in this improvement stage are looking for suggestions for improvements. The 5W+1H tools analysis was carried out by conducting interviews and discussions to get the right recommendations to reduce the problem of damaged PCB connector which can be seen in Table 1.

Table 1. 5W +1H Analysis for damage PCB connector

Factor	What	Who	When	Why	Where	How
Man	The operator does not pay attention to the installation	Production Supervisor	In selection and installation of components	Rush in installation	Component assembly	Need more supervision and training
Material	No re-verification of connectors from suppliers	Warehouse Production Supervisor	Incoming components from suppliers	Similar connector components	Component selection process	Rechecking and add specific label
Method	Connector components are not neatly organized	Production Supervisor	Mounting components	PCB connector assembly is out of order	Component selection process	Arranging the working area based on process order

The last stage is control where this activity is by comparing the results before and after the improvement which aims to determine the success parameters of the improvement activities. The data used as a comparison is data on the number of defects that occurred in October 2022. The data that has been collected after improvement are shown in table 2. Comparison of data is done by comparing DPMO values and determining the sigma level. Comparison of the P control chart before and after the improvement can be seen in Figure 5 where the data after the improvement shows that the distribution is still within the control limits

Table 2. Total Production and Total defect in production during October 2022

Total Production (unit)	Damage PCB Connector
1124	52

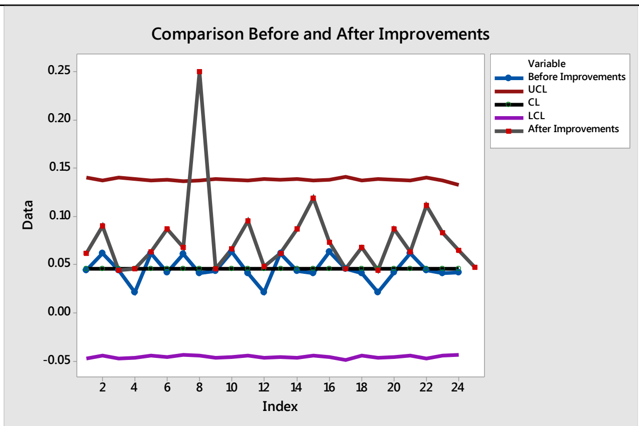

Figure 5. Comparison of P-Control chart before and after improvements

The comparison of the DPMO results and the sigma level is then used as a comparison between the results before and after the improvement. DPMO can be calculated by dividing the number of defects by the total number of units produced, then multiplying by one million units. After having the DPMO value, then determine the sigma value from the Motorola conversion table. The DPMO results after improvements had decreased, and the sigma level had increased. The results can be seen in Table 4.

Table 4. Comparison DPMO and Sigma Level

Performance	Results		Difference	Percent
	Before	After		%
DPMO	76,43 Unit	46,26 Unit	30,17	39,47% ↓
Level Sigma	2,92	3,18	0,25	8,64% ↑

The calculation results of the DPMO value experienced a significant decrease of 39.47% of the total defects after carrying out repair activities. The decrease in the DPMO value obtained after the repair was caused by a decrease in the number of defects on the production line, thus proving that the repairs made were effective. Whereas at the sigma level there was an increase of 8.64% from before the repair which was also caused by a decrease in the number of production defects after the improvement was carried out.

Discussion

The results of the research on solving problems in the production process are carried out to reduce the number of defective products. DMAIC is commonly used as a tool that helps management as well as other stakeholders to determine problems and solutions (Boon Sin et al., 2015). Based on the case study at this power supply company, it was found that the type of defective PCB connector is the most dominant type of defect. Based on this, then data collection and processing is carried out to prove and look for possible causes of problems which are caused by three factors, namely the human factor, material factor and method factor.

The Improvements made to human factors problems by providing training and knowledge of the impact of improper component installation. Besides that, a streamlining process was also carried out which eliminated the work elements of the operator so that the operator had time to re-check the assembled components before proceeding to the next process. Improvements to material factors, namely the process of checking or re-verifying by the production party before these components are used in the production line. In addition, special labeling is also needed to prevent the problem from recurring.

Improvements to the method factor were carried out by re-engineering the problem of component placement in the operator's work area so that the assembly process could be carried out more easily and sequentially according to the procedure. The basic principles of being sort, set in order, shine, standardize, and sustain (5S) can be an additional solution in structuring the work area (Ribeiro et al., 2019). This was also proven in a study in a manufacturing company that this principle would be easier if it was properly understood by management and employees at the company (Senthil Kumar et al., 2022). The application of tools in problem solving is also very necessary which will make the production line leaner (Dias et al., 2019).

Conclusion

The DMAIC used in this study proves that through this framework one can find the root causes of the problems that occur. Problems with man, material and method factors are the source of the high production defects of power supplies caused by damaged PCB connectors. Based on quantitative calculations using DPMO and sigma levels it was found that the DPMO value experienced a significant decrease before repair (76.43 units) and after repair (46.26 units). This 39.47% decrease indicates the success rate of the damaged PCB connector problem in the power supply assembly process. For the sigma level, based on the interpolation carried out, it was found that the sigma level increased before the repair (2.92) and after the repair (3.18). This is enough evidence that the DMAIC framework is very appropriate to be used in this power supply assembly company as a tool to solve problems in the production line. What can be recommended to the management of power supply producing companies is that training on understanding the DMAIC framework can be carried out on a regular basis so that it becomes a new culture in carrying out company operations. In the future, this research can be developed further by looking at the sustainability of quality control improvements by implementing the Plan, Do, Check, Action (PDCA) process to be able to see opportunities for quality improvement related to power supply production.

References

Ai, Z., Heinle, I., Schelske, C., Wang, H., Krause, P., & Bäck, T. (2021). A Classification-based Solution for Recommending Process Parameters of Production Processes Without Quality Measures. *Procedia Computer Science*, *180*, 600–607. https://doi.org/10.1016/J.PROCS.2021.01.282

Boon Sin, A., Zailani, S., Iranmanesh, M., & Ramayah, T. (2015). Structural equation modelling on knowledge creation in Six Sigma DMAIC project and its impact on organizational performance. *International Journal of Production Economics*, *168*, 105–117. https://doi.org/10.1016/J.IJPE.2015.06.007

Deeb, S., Haouzi, H. B. el, Aubry, A., & Dassisti, M. (2018). A generic framework to support the implementation of six sigma approach in SMEs. *IFAC-PapersOnLine*, *51*(11), 921–926. https://doi.org/10.1016/J.IFACOL.2018.08.490

Dias, J. A., Ferreira, L. P., Gonçalves, M. A., Silva, F. J. G., & Ares, E. (2019). Analysis Of An Order Fulfilment Process At A Metalwork Company Using Different Lean Methodologies. *Procedia Manufacturing*, *41*, 399–406. https://doi.org/10.1016/J.PROMFG.2019.09.025

Godina, R., Pimentel, C., Silva, F. J. G., & Matias, J. C. O. (2018). Improvement of the Statistical Process Control Certainty in an Automotive Manufacturing Unit. *Procedia Manufacturing*, *17*, 729–736. https://doi.org/10.1016/J.PROMFG.2018.10.123

Kumar Phanden, R., Sheokand, A., Kumar Goyal, K., Gahlot, P., & Ibrahim Demir, H. (2022). 8Ds method of problem solving within automotive industry: Tools used and comparison with DMAIC. *Materials Today: Proceedings*, *65*, 3266–3272. https://doi.org/10.1016/J.MATPR.2022.05.383

Luo, T., Wu, C., & Duan, L. (2018). Fishbone diagram and risk matrix analysis method and its application in safety assessment of natural gas spherical tank. *Journal of Cleaner Production*, *174*, 296–304. https://doi.org/10.1016/J.JCLEPRO.2017.10.334

Müller, R., Scholer, M., Schirmer, L., & Blum, A. (2020). Tolerance management in robot-based assembly optimizes product, process and system deviations. *Procedia CIRP*, *93*, 1103–1108. https://doi.org/10.1016/J.PROCIR.2020.04.027

Pacana, A., Czerwinska, K., & Dwornicka, R. (2021). Analysis of quality control efficiency in the automotive industry. *Transportation Research Procedia*, *55*, 691–698. https://doi.org/10.1016/J.TRPRO.2021.07.037

Park, C., Ouyang, L., & Wang, M. (2021). Robust g-type quality control charts for monitoring nonconformities. *Computers & Industrial Engineering*, *162*, 107765. https://doi.org/10.1016/J.CIE.2021.107765

Powell, D., Magnanini, M. C., Colledani, M., & Myklebust, O. (2022). Advancing zero defect manufacturing: A state-of-the-art perspective and future research directions. *Computers in Industry*, *136*, 103596. https://doi.org/10.1016/J.COMPIND.2021.103596

Ribeiro, I. M., Godina, R., Pimentel, C., Silva, F. J. G., & Matias, J. C. O. (2019). Implementing TPM supported by 5S to improve the availability of an automotive production line. *Procedia Manufacturing*, *38*, 1574–1581. https://doi.org/10.1016/J.PROMFG.2020.01.128

Samuel, R., Rajesh, M., Rajanna, S., & Franklin, E. (2021). Implementation of lean manufacturing with the notion of quality improvement in electronics repair industry. *Materials Today: Proceedings*, *47*, 2253–2257. https://doi.org/10.1016/J.MATPR.2021.04.200

Senthil Kumar, K. M., Akila, K., Arun, K. K., Prabhu, S., & Selvakumar, C. (2022). Implementation of 5S practices in a small scale manufacturing industries. *Materials Today: Proceedings*, *62*, 1913–1916. https://doi.org/10.1016/J.MATPR.2022.01.402

Shen, Y., Zhou, J., Pantelous, A. A., Liu, Y., & Zhang, Z. (2022). A voice of the customer real-time strategy: An integrated quality function deployment approach. *Computers & Industrial Engineering*, *169*, 108233. https://doi.org/10.1016/J.CIE.2022.108233