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A lean six sigma approach to glue problem in a furniture manufacturing company

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ABSTRACT

The main focus of this research paper is to shed light on the challenges encountered by the chair production department employees when it comes to identifying and locating glue residue after the assembly process. This issue arises due to the transparent nature of the glue, making it difficult to detect and subsequently negatively impacting the overall quality of the chairs in the polishing department. To tackle this problem, various experiments and tests were conducted, which are thoroughly discussed in this paper. The findings of this study are not only applicable to the specific manufacturing company under investigation but also to other companies within the industry that face similar difficulties in detecting defects caused by transparent glue. As a result, a new method for detecting glue defects is proposed, which can be adopted by various industries encountering similar challenges.

1. Introduction

Today, the business landscape is characterized by intense competition, which compels companies to seek strategies that will give them an edge over their rivals in order to survive. As a result, the effectiveness of conventional cost and management accounting systems has diminished, necessitating the adoption of contemporary alternatives. Examples of these modern systems include Activity-Based Costing (ABC), Just-in-Time (JIT) production, and Quality Cost Systems. In response to the growing emphasis placed on quality by customers, companies have shifted their focus towards producing high-quality products.

To enhance the standard of their products and services, as well as address any flaws within their production systems that result in subpar quality, companies must have an understanding of and monitor quality costs. By effectively analyzing these costs, companies can elevate their level of quality and reduce expenses through the careful management of quality cost components and the eradication of underlying causes that contribute to the production of substandard goods (Siswanto et al., 2022).

This paper highlights the issues faced by the chair manufacturing department personnel in locating glue residue due to its transparent color. The paper provides a detailed account of the experiments conducted to find a solution to this problem. The research is important because it addresses a common issue faced by many manufacturing industries where the quality of the product is compromised due to the inability to detect defects caused by transparent glue. The study provides a practical solution to this problem, which can be implemented by other industries facing similar issues. The research also highlights the importance of continuous improvement to solve problems in the manufacturing process.

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2. Literature Reviews

Quality improvement methodologies such as Total Quality Management (TQM), Lean Manufacturing (LM), and Six Sigma continue to be embraced by organizations as they seek to enhance the output of their business processes, whether targeted at internal or external customers. Effective management of quality remains a fundamental aspect of operations strategy, with Six Sigma serving as a valuable approach for eliminating defects and ensuring customer satisfaction (Simanová & Sujová, 2022). The effectiveness of the company's quality control measures greatly influences its ability to reduce product failure rates and ensure the production of high-quality final products. When the company has strong control measures in place, the risk of incurring high costs due to product failure is significantly reduced. According to Al Choir (2018), control refers to the act of monitoring and ensuring that performance aligns with the established plan. Additionally, research conducted by Magar and Shinde (2014) demonstrates the effectiveness of implementing 7 Quality Control Tools, which facilitate the identification, implementation, and tracking of quality improvements further indicating a positive change in the production process and affirming the positive impact of quality control on the final product.

In industries such as furniture manufacturing, it is important to find effective ways to prevent faulty production. Traditional and statistical methods are useful for identifying defective products, but not as effective in preventing them (Ratnasingam, 2022). A study conducted by Ersöz et al. (2022) aimed to evaluate the furniture production sector in identifying the sources and causes of defective production in each department. By identifying these causes, the company could prevent the production of faulty products. The study offered an approach to improve the quality of the production process and prevent errors in advance. Another furniture manufacturing company operating in the outdoor chair sector, specifically stainless steel chairs, conducted research to address product delays. The focus was on a particular type of chair that had a significantly higher delay rate compared to others. During the production process of the radius chair, various forms of waste were identified, including defective products and work-in-process inventory at the polishing workstation. To tackle this issue, implementing Lean Manufacturing was considered. The initial step involved identifying waste through Value Stream Mapping and the Waste Assessment Model. Subsequently, the root cause analysis was performed using the 5 why's methodology (Ramdani et al., 2022).

3. Wooden Chair Manufacturing Process

High-quality timber is utilized in the manufacturing of chairs. The timber (beechwood) is delivered to the factory by trucks and is carefully unloaded and transported to the designated processing area. The chair production involves the use of four different thicknesses of timber: 10, 8, 6, and 5. In the initial stage, the appropriate timber size is selected for each chair and calculations are made to determine the required amount of timber. The timber is then transported to the chair department and undergoes sizing and sawing processes. Planning and thickness machines are utilized before the pieces are fed into the CNC machines. The next step involves opening mortise and tenon joints. Subsequently, all the pieces go through a thorough sanding process using drum, caliber, table, and belt sanding techniques. Once the sanding process is complete, the assembly process begins, which is divided into two stages: partial assembly and complete assembly. The parts that form the skeleton frame are initially combined using glue in the partial assembly stage, and then the partially assembled parts are further combined to create the complete skeleton frame. Once the product reaches the skeleton frame stage, each component is carefully sanded using orbital sanding, random orbital sanding, and manual sanding. Subsequently, the product undergoes thorough quality control before being sent to the polishing department.

4. Problem Description

The manufacturer utilizes solid wood which a pure wood material is obtained by simply cutting and shaping the tree in the desired shape without any artificial intervention. This results in a 100% natural material. Chair production primarily relies on the use of beech wood, a robust and sturdy hardwood with exceptional mechanical properties. It has high resistance to compression, though less so to bending or tension. It tends to warp when exposed to changes in humidity. The wood has a fine texture and possesses the ability to withstand shocks and wear, as well as being easily polished (Desch & Dinwoodie, 2016). Due to its bending qualities, it is a highly sought-after material in the furniture industry, especially for crafting chairs.

During the assembly process of the frame pieces, polyvinyl acetate (PVA) glue is utilized. The resulting adhesive does not emit any odors or hazardous fumes and can be handled safely without any protective gear. PVA glue solidifies when there is adequate air circulation and dries most rapidly at room temperature. The strongest bond is achieved when the glued pieces are clamped together. This glue is white in color but becomes transparent once dry. PVA wood glue is specifically designed for woodworking and carpentry projects. One of the primary advantages of using PVA wood glue for wood joining is its exceptional ability to adhere to and permeate porous surfaces like wood. Additionally, PVA wood glue retains slight flexibility over time, allowing for the application of pressure and preventing wood pieces from breaking apart under minimal pressure. Steps of skeleton frame assembly are as follows:

- Using a brush to spread a layer of glue over the pieces of wanted to glue together
- Remove any excess or spills immediately using a damp cloth
- Press the pieces together and make sure the glue spreads evenly
- Use clamps to hold the pieces securely
- Leave for 24 hours before removing the clamps.
- Sand off any dried excess glue.

The employees in the chair department were encountering challenges when it came to finding excess glue because of its transparent appearance. This inability to easily detect glue residue was causing delays and the need for rework in the polishing process due to visual defects as shown in Fig. 1. Table 1 visualizes the interaction where the focus i on the output category.

Table 1
SIPOC analysis

Suppliers	Inputs	Requirement	Process	Outputs	Requirement	Customers
Chair Department	Order of the specific models needed to produce	Order items should be listed on manufacturing planning	Clients order	Manufactured chair models	No cracks on the chairs	Polishing Department
		Models should be specified			No bruises on the chairs	
		Each items quantity must be specified	Chair Production		No abrasive marks on the chairs	
	Timber	Dry and 1st class			No skeleton dimension defect on the chairs	
		No cracks			No glue residue on the chairs	
		No worms	Delivered chairs		No putty residue on the chairs	

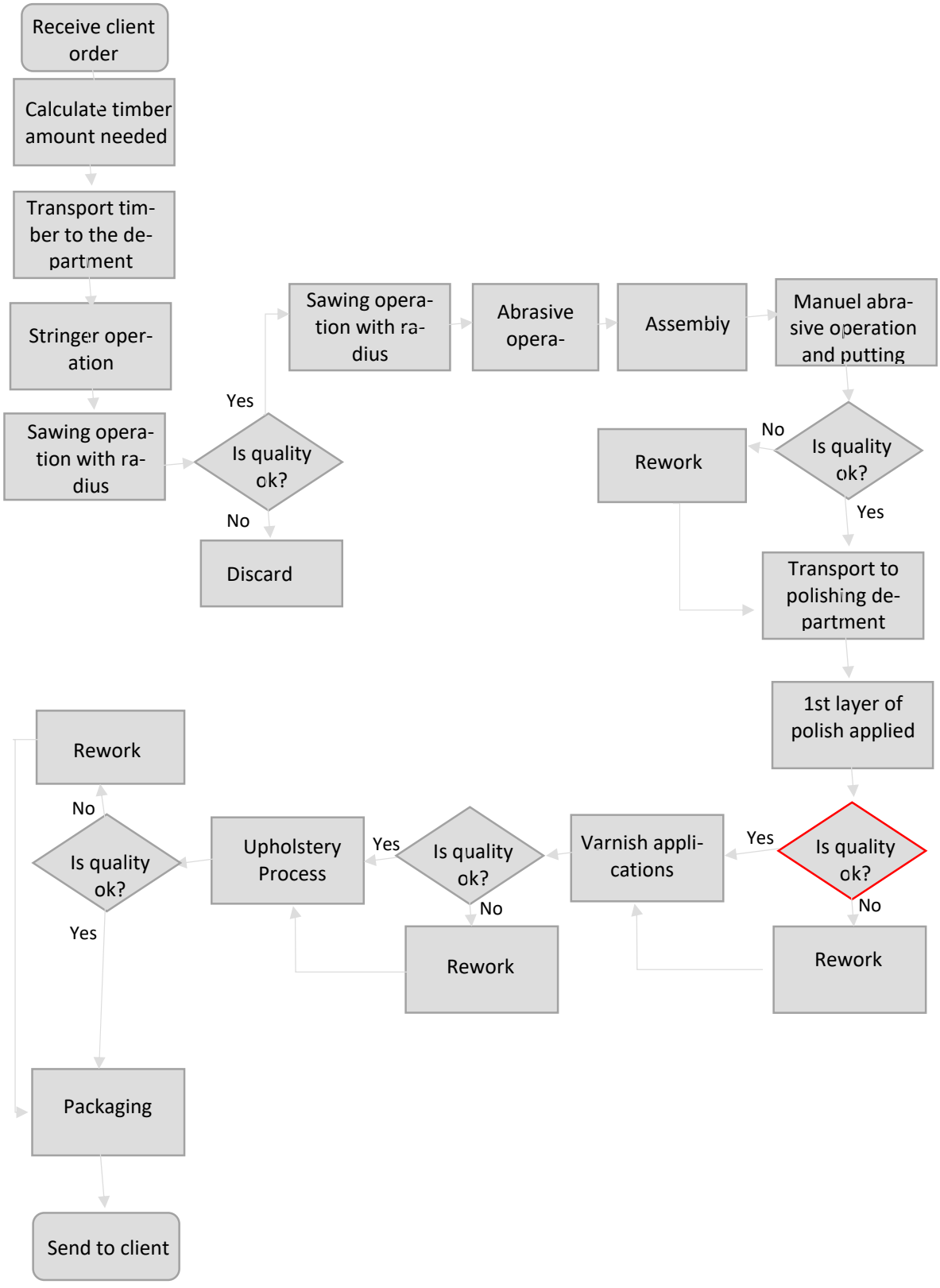


Fig. 1. Process flow chart where the defect point is outlined

5. Analysis

To determine whether the undetected glue residue from the chair department poses a significant problem Statistical process control and Pareto analysis we conducted, which revealed the extent of the rework load as shown in Fig. 2 and Fig. 3.

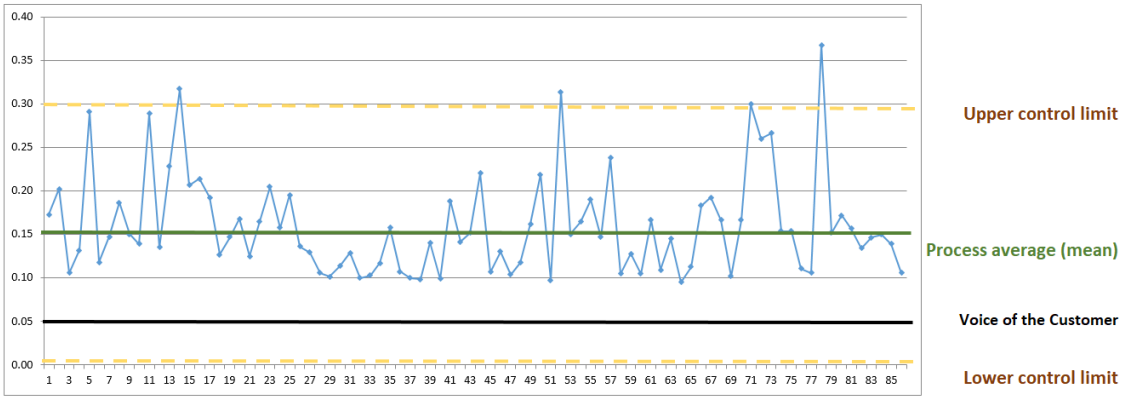


Fig. 2. Voice of the customer analysis of seven month glue defect in polishing department

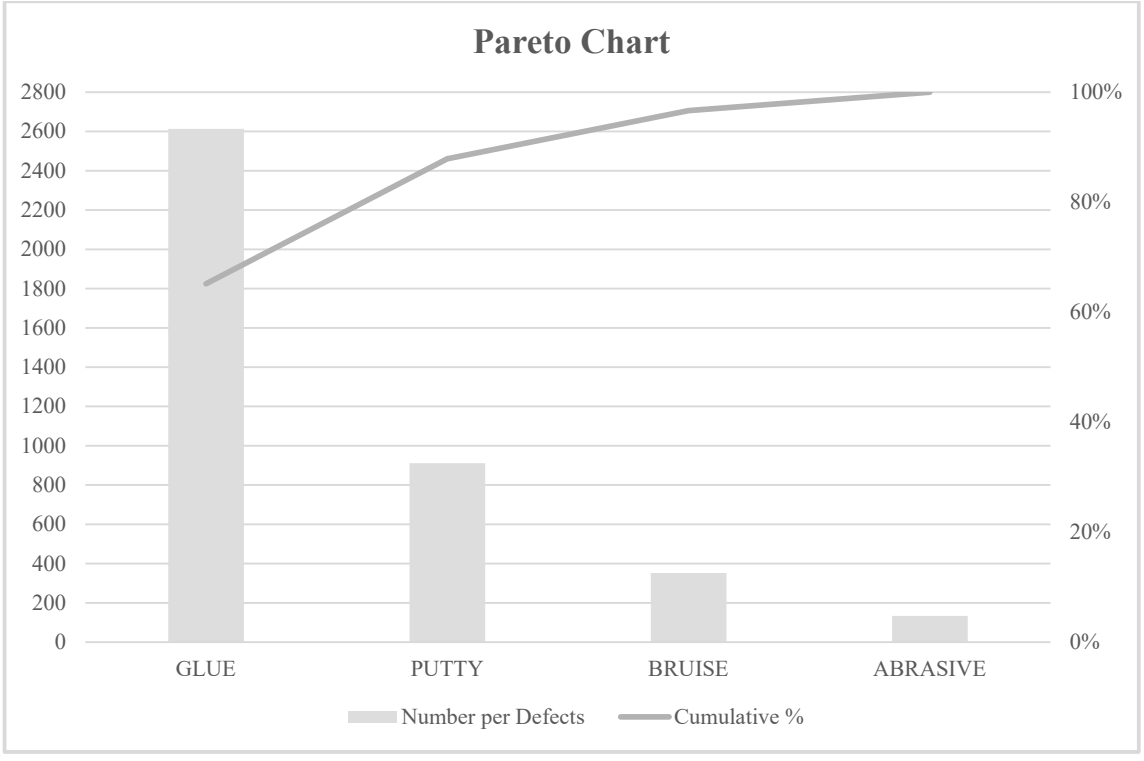


Fig. 3. Pareto analysis in polishing department

Gemba walk, Fishbone, and 5-why analysis were further conducted to get a better understanding of the root cause of the problem as shown in Table 2, Figure 4, and Table 3. The analysis clearly demonstrates to focus on defect waste which is caused by undetectable colorless glue.

Table 2
Gemba analysis of the process

	7 Wastes	Meaning	Wastes in process
T	Transport	Unnecessary movement of items, data, equipment.	Rework needed product is transported to the rework area
I	Inventory	Storage of unnecessary goods or data	-
M	Motion	Unnecessary movement of people	In chair department quality control area rework needed product is given back to the employee. In prepolishing quality control area rework needed product is transported manually by the employee
W	Waiting	Waiting for inputs, approval, confirmations	In some cases polish colour of the order is decided after production has been completed (thus products are waiting in warehouse). Before prepolishing control we must wait for paint to dry
O	Overprocessing	Too many data, too many unnecessary details not needed by Customer	-
O	Overproduction	More items than customer needs	-
D	Defect	Items not meeting customer expectations	• Glue residues that escape chair department operators that are found by chair quality control employee which are sent back • Putty residue that escape chair department operators that are found by chair quality control employee which are sent back • Glue defects that can be visible only after polish which inturn need rework • Putty defects that can be visible only after polish which inturn need rework
8TH Waste	Unused creativity of people	Not involving people, lack of feedback	Employees reluctant on expresing their ideas

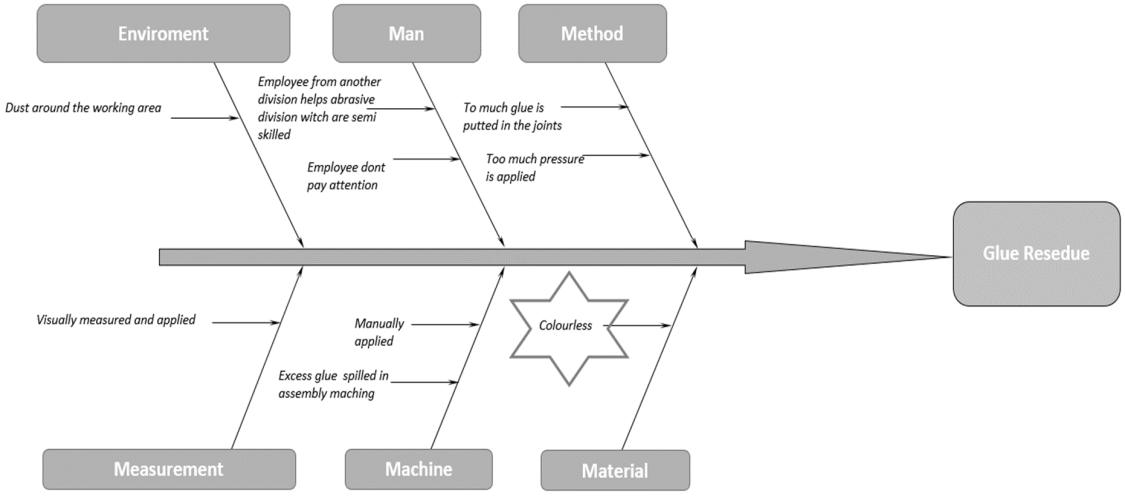


Fig. 4. Fishbone analysis of the defect

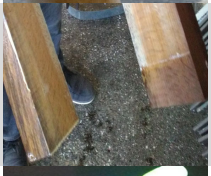
Table 2
5-why analysis of the issue

Cause	1. Why?	2. Why?	3. Why?	4. Why?	5. Why?
Glue resedue on chairs in polishing department	Products came with glue defect from chair department	Control personnel from chair department didnt notice the defect	Glue residue hard to detect when applied on the raw material	Glue defect is visible after first layer of polish	Glue used is colorless
	Products came with glue defect from chair department	Workers and control personnel from chair department didnt notice the defect	Workers didnt pay attention	Employees that arent fully qualified from other division helps abrasive employees	Time limit in production and number of qualified sander is limited
	Products came with glue defect from chair department	Control personnel from chair department didnt notice that residue of excess glue spilled is still there although cleaned	Glue residue hard to detect when applied on the raw material	Glue defect is visible after first layer of polish	Glue used is colorless

6. Experiments and a new proposed control system

After analysis of the defect, it was discovered that the root cause of the issue was using transparent glue which led to different ideas to make the glue visible to the naked eye. Making glue visible was not the only problem, however, because any modifications made had to go through weather, frame, and polishing testing to make sure the structure was not compromised. Table 3 demonstrates the results of different alternatives tested. The visibility test is about glue being visible. The water test is conducted after the visibility test where the sample piece is left in a water tank for one month to check if the pieces will separate. If the alternative passes the water test, the heat test is implemented which is leaving the soak piece under the sun for a month to see if it will crack or separate. If the alternative passess all three tests the piece is sent to the polishing department to check if varnish has any negative interaction.

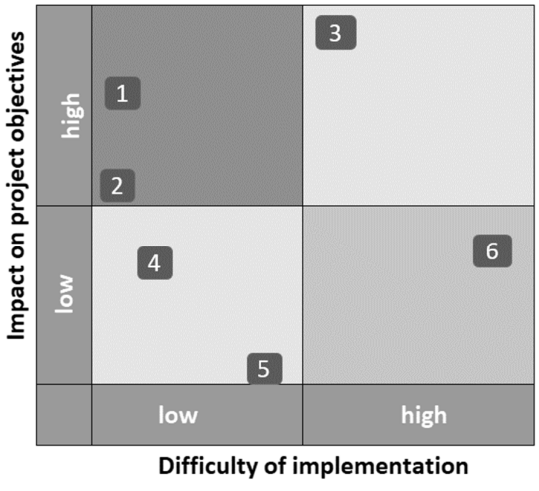
Table 3
Summary of the tests conducted on the alternatives

Alternative	Visibility	Water Test	Heat Test	Polishing	Sample
Adding coloring in glue	Pass	Pass	Fail	N/A	
Cellulosic thinner on frame to make resedue visible	Fail	N/A	N/A	N/A	
New brand colored glue	Pass	Fail	N/A	N/A	
Mixture	Pass	Pass	Pass	Pass	

Among the tried alternatives the mixture was the only one that showed promise. The proposed mixture consists of phosphor and regularly used brand glue in the production. The mixture has been tried to see if it illuminates under UV light for visibility. The mixture was then applied to a fixture to see if it would give the same result. Then it was tested to control if the mixture's composite would make it so that after the sanding process the invisible glue would still be seen with UV light. After the proposed mixture passed all the tests as shown in Fig. 5 revised glue has been put into action for some controlled models.

Fig. 5. Trial steps for proposed mixture

Upon finding the solution impact difficulty matrix as shown in Figure 6 was drafted together with an implementation plan including different phases as shown in Table 4, Table 5, and Table 6.



List of improvements	Glue resedue on chairs in polishing department
1.	*List of personnel name with occured defect to be filled by chair control personnel to allocate them better and know who needs to pay attention to what defect.*
2.	*Increase lux of light for better illumination.*
3.	*Make glue visible without changing the brand we use.*
4.	*Presentation of glue mistakes and where they are usually located.*
5.	*Talk to employees about their solution ideas. Making weekly rounds to talk to people about process improvement ideas they might have.*
6.	*Giving training to each employee of chair department.*

Fig. 6. Impact difficulty matrix for improvements to avoid glue defects

Table 4
Improvement implementation action phase

1. Actions			
Improvement	*Impact on objective*	*Start & finish date*	*Status*
List of personnel name with occured defect to be filled by chair control personnel	High	September-October 2019	Completed
Increase lux of light for better illumination	Medium	May 2019	Completed
Presentation of glue mistakes and where they are usually located.	Medium	January 2020	Completed
Mixture is tried to is if it is visible under uv	High	November 2019	Completed
Mixture tested to see if adhesive properties remains the same under different climate and polish	High	November 2019	Completed
Trial run with new glue mixture	High	December 2019	Completed
Full production with new glue mixture	High	January 2020-Ongoing	Completed

Table 5
Improvement implementation training phase

2. Trainings			
Training objectives	*Participants*	*Place*	*Status*
Personnel allocated to proper posts according to the list in order to minimize defects detected during control	Chair department personnel	Production area	Completed
Presentation of glue mistakes and where they are usually located to inform employee where to pay special attention	Chair department personnel	Meeting area	Completed
Getting chair personnel used to how to use the uv light and making sure that the device is also used by abrasive peronnel not just by control employee.	Chair department personnel	Production area	Completed

Table 6
Improvement implementation communication phase

3.Communication			
Audience	*Key Message*	*Sender*	*Status*
Production responsible	Mixture is tried to is if it is visible under uv	Quality Manager	Completed
Production responsible	Mixture tested to see if adhesive properties remains the same under different climate and polish	Quality Manager	Completed
Production employees	Trial run with new glue mixture	Production responsible and Quality manager	Completed
Production responsible and employees	Getting chair personnel used to how to use the uv light and making sure that the device is also used by abrasive peronnel not just by control employee	Quality Manager	Completed
4. Standard Operating Procedure			
Audience	*Key Message*	*Sender*	*Status*
Production responsible	How much ingredient has to be put in the glue	Quality manager	Completed

During the implementation process, UV flashlights was provided to the manual sanding pesonnels to inspect the products. It was calculated that the payback period for the UV lights was 1.5 months. Figure 7 shows the improvement track by comparing months and years 2019 and 2020 where 2020 is the starting point of the proposed new process.

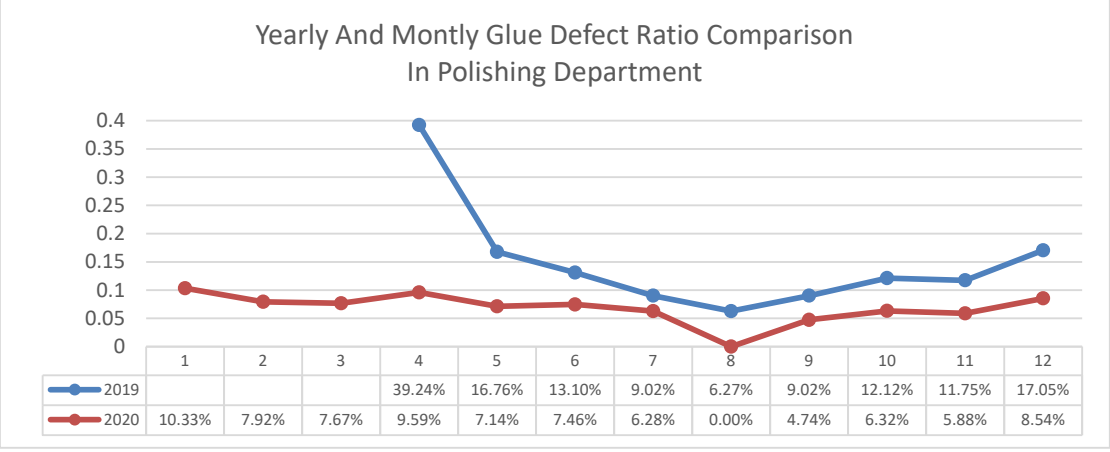


Fig. 7. Yearly and montly glue defect ratio comparison in polishing department

In addition, after observing the chair production process further change was implemented by providing UV flashlights to the glue cleaning personnel thus making them responsible for the quality of their operation. Fig. 8 shows the improvement track by comparing months and years 2021 and 2022 where July 2022 is the start point of the improved process.

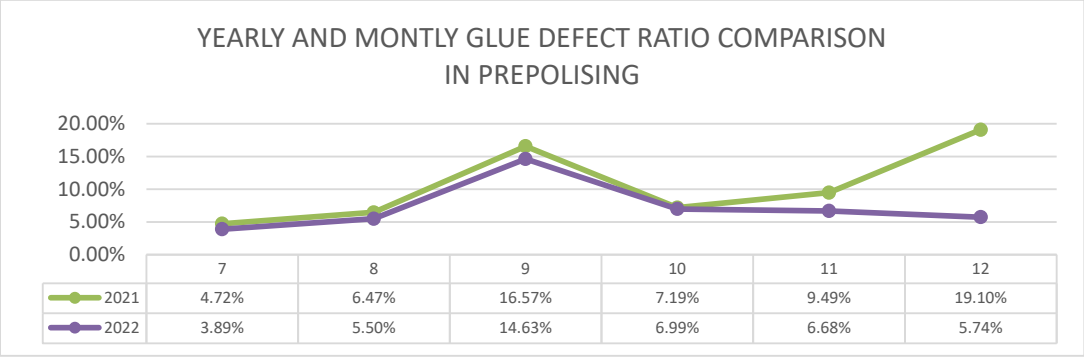


Fig. 8. Yearly and montly glue defect ratio comparison in polishing department after improvement

7. Conclusion

This research paper addresses the problem of inefficient glue detection in the chair department of an industrial facility thus leading to rework in the polishing department. A new solution that makes the glue residue visible is proposed. The proposed solution involves applying a mixture of phosphor and glue to beechwood chairs. This mixture is then tested to see if it makes the glue residue visible under UV light. Water and heat tests were conducted to ensure the reliability of the revised glue. The research also includes other considered alternatives. Before and after process comparison is shown for the proposed solution.

The implementation of the phosphor and UV light solution in the chair department resulted in significant cost savings and improved efficiency with an average of 8% decrease in glue defects. The new method successfully detected previously invisible glue residue, reducing the need for rework and saving both time and money. The research findings suggest that this newly found solution has the potential for wider applications in industries facing similar glue detection problems.

References

Al Choir, F. (2018). Pelaksanaan quality control produksi untuk mencapai kualitas produk yang meningkat (Studi Kasus PT. Gaya Indah Kharisma Kota Tangerang). *Jurnal Pemasaran Kompetitif*, *1*(4), 1-20.

Desch, H. E., & Dinwoodie, J. M. J. M. (2016). *Timber: structure, properties, conversion and use*. Bloomsbury Publishing.

Ersöz, T., Güven, İ., & Ersöz, F. (2022). Defective products management in a furniture production company: A data mining approach. *Applied Stochastic Models in Business and Industry*, *38*(5), 901-914.

Magar, V. M., & Shinde, V. B. (2014). Application of 7 quality control (7 QC) tools for continuous improvement of manufacturing processes. *International Journal of engineering research and general science*, *2*(4), 364-371.

Ramdani, M. R., Prasetyaningsih, E., & Satori, M. (2022, January). Penerapan Lean Manufacturing untuk Mereduksi Waste pada Proses Produksi Radius Chair di PT. Helie Furniture Indonesia. In Bandung Conference Series: Industrial Engineering Science (Vol. 2, No. 1, pp. 16-25).

Ratnasingam, J. (2022). Production Flow in Furniture Manufacturing. In *Furniture Manufacturing: A Production Engineering Approach* (pp. 29-41). Singapore: Springer Singapore.

Simanová, Ľ., & Sujová, A. (2022). The Impact of Continuous Improvement Concepts on the Performance of Furniture Production Processes. *Central European Business Review*, *11*(1), 111.

Siswanto, D. J., Nuroktavia, D. A., Wahyudi, I., & Syah, T. Y. R. (2022). The Effect of Production Planning and Quality Control on The Final Product. *Journal of Social Science*, *3*(6), 2128-2136.