



Research Article

Productivity improvement in manufacturing of furniture using quality function deployment approach

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ABSTRACT

Micro, Small, and Medium Enterprises often face challenges in balancing customer demands, design attributes, production parameters, and productivity. Research has been done on matrix diagrams, correlations, tabularization techniques, and quality deployments, but none of them have linked productivity to design qualities and customer needs. This study aims to evaluate productivity and the related monetary savings by applying a Lean management tool- Quality Function Deployment. Furthermore, strapping focuses on the ‘Voice of the Customer’ of furniture products’ profile. The focal objective has been to identify specific process improvements related to design features and assess the impact of these enhancements on overall productivity. By integrating design quality with operational improvements, the study seeks to demonstrate the savings through increased productivity.

During the use of ‘Quality Function Deployment’, non-value-adding elements in the furniture manufacturing process were eliminated. The implementation of Lean Six Sigma methodology further enhanced the overall quality management strategy. Data analysis and subsequent execution led to a substantial 21.16% increase in productivity, translating to annual cost savings of INR 55,200. The significance of design qualities (named as Technical Requirements), was assessed using Quality Function Deployment, providing a foundation for developing an optimized furniture production process. The integrated application of Lean Six Sigma and Quality Function Deployment has demonstrated the potential to reduce processing times, boost productivity, and increase profitability without compromising customer satisfaction. The approach emphasized the importance of collaborative Lean management, maintaining a well-organized workplace, improving process efficiency, and eliminating non-value-adding activities. In essence, this study uniquely contributes to operational optimization by focusing on the relationship between Technical Requirements and the Voice of the Customer in furniture manufacturing processes. This approach can be widely applied to various manufacturing industries.

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INTRODUCTION

Productivity enhancement is a persistent challenge in various industries. Quality Function Deployment (QFD) is a valuable tool for data collection and analysis, facilitating the translation of customer needs into engineering design characteristics. By integrating marketing, design, engineering, and other relevant functions, QFD optimizes product development.

The furniture industry, characterized by intense competition and rapidly changing consumer preferences, is compelled to continually improve productivity. To effectively address customer needs and incorporate them into product attributes, QFD could offer a valuable tool [1-3].

The study describes a procedure for prioritization of ‘Technical Requirements’ (TRs) that best fulfil the customer voice, benchmarking the competitor level to fulfil the customers’ needs, and improving the manufacturing processes and resources through opinion polls, a rating matrix, along with a Six Sigma approach. More specifically, it is the DMAIC (Define- Measure- Analyze- Improve- Control) approach. The findings of this study are valuable to operations excellence practitioners across various manufacturing sectors, enabling them to enhance productivity and profitability. The overall flow of the study is shown in Figure 1.

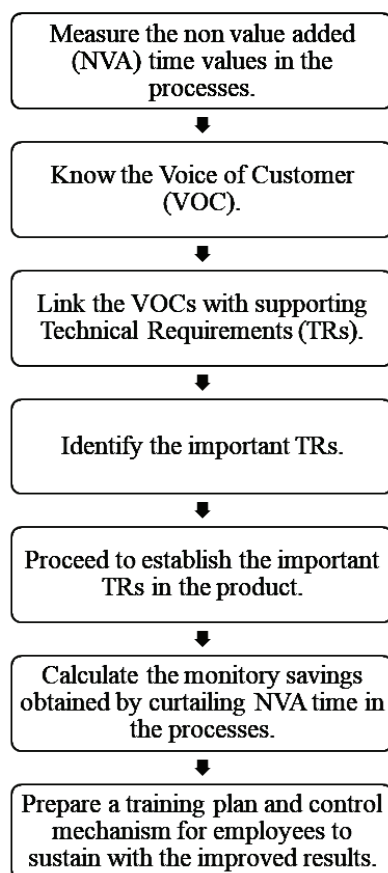


Figure 1. Chart of steps in the study.

Literature Review

A literature review on comprehending the existing usage of QFD, its conjunction with other concepts and methodologies, and the relevant gaps is made in the first phase. Out of the several research material reviews, only a handful of the most relevant cases to our study are chosen. Below are the takeaways-

According to a poll conducted by an organization with sixty participants, there is a significant correlation between customer happiness and QFD, covering several strategic aspects and viewpoints. QFD can work in tandem with other Lean techniques to get a comprehensive productivity result. This can be illustrated by utilizing an innovative approach to problem-solving (called TRIZ), in conjunction with QFD [2,3]. An Ethiopian company that manufactures leather shoes used ‘Failure Mode Effect Analysis’ (FMEA) in conjunction with QFD to assess collaborative design features. FMEA is a preventive risk analysis and hence possesses the capability to reduce external breakdown costs, leveraging improvement in productivity [4].

An integrated model for capturing engineering students’ needs from the viewpoints of educational institution facilities and infrastructure was developed using a Seroquel model (service quality) in conjunction with QFD, which has accounted for probable risks in the usage of traditional educational methods [5].

These studies aimed to understand the use of QFD, which had assumed a diversified segment of products that has helped to create a basic theoretical framework for this research work.

The diversity in the references, particularly in terms of case studies or papers on similar QFD applications in other industries, has been made, which could provide a more robust foundation for the QFD implementation. A summary is made in Table 1 below

The intention of the above reviews was to judge the scalability of QFD in product profiles other than furniture. It was required to comprehend whether there could be any possibility to use QFD as a general approach for the fulfillment of the aim of this research. While casting the use of QFD for furniture, it was beneficial to develop a know-how of its apt application. Below are the takeaways-

Table 1. Other studies

Product segment	Author(s)
Internet banking services	[6]
Supply chain digitization	[7]
Cell phone closed-loop supply chain optimization	[8]
Service expectations of low-cost airlines	[9]
Autonomous electric car	[10]
Renewable Energy for different vehicles	[11]
Smart home products	[12]

As a general practice, the correlations between VOCs and TRs are described by the three correlation values, 9,3, and 1 [6,7]. The 9 and 1 values are retained in this study. However, another value could be in the middle of this (i.e., 5). A value of 4 is taken for the safer side. A prioritization between VOCs and TRs was noted for exercising the roof part of QFD. A weighted sum technique is feasible for the elements that are not of the same nature. QFD could consider customer priorities in the ranking based on the customer perspectives. A fuzzy-based logic can be suitably used for service industries. However, for the product industry, it has a different consideration [8,9]. A Kano model approach that divides the customer requirements as basic, intermediate, and delighter, helps to identify the customer priorities scale. It can be associated with QFD to derive both the benefits [10,11].

An integration of TRIZ (an English meaning is ‘Theory of Inventive Problem Solving’) with QFD is feasible. The concept of assembling identical or similar parts to perform parallel operations was executed while devising the process enhancements in furniture manufacture. A sustainable user experience theme was established while inviting the ranking of wood selection for the coffee table [12].

Noted with the framework aspects from the above literature studies, it was further aimed to know the use of QFD typically for furniture products, specifically to learn how design enhancements are performed or how manufacturing excellences are accounted for. Information was collected from a partial literature review of the past ten years’ relevant research publications, specifically to know the customers’ expectations, fulfillment trends, scope, and limitations. Table 2 describes this.

The use of the Lean Six Sigma methodology and its operational excellence approach, with respect to Indian work culture, has also been exercised in the research. Few of the process enhancements were derived from the fundamental Lean lacunas like workmanship and discipline, which proved a time saving of 66.5% in a panel cutting

workshop through industrial engineering interventions. In today’s competitive landscape, maintaining a strong commitment to both internal and external customers is crucial. Effective mechanisms must be in place to capture and address their evolving needs [20,21].

Various literature references have provided a critical evaluation of the application and applicability of QFD as well as Lean operations along with the related design process. It has revealed the importance of QFD with respect to design and development and expressed implicitly the need for further investigation to employ productivity. QFD mix, or gathering the Voice of the Customer and using the associated qualities in the product or services, has been in use in crafting the design; however, linking the outcome to productivity needs to be exercised [1].

While previous research has utilized QFD to capture and analyze the Voice of the Customer (VOC), it has often neglected the optimization of batch manufacturing processes by eliminating non-value-added activities (NVAs). While these studies emphasize the product development quotient, the manufacturing quotient falls outside their scope.

The existing literature highlights a gap in the application of QFD to bridge the link between design and operational excellence for improved productivity. This research study addresses this gap through applied research focused on the furniture industry. Specifically, the study aims to frame a QFD approach for common furniture items such as chairs, sofas, and dining tables, to enhance productivity.

RESEARCH PARTNER

This research study was conducted in collaboration with Prabha Furniture (Hereafter called Prabha), a Pune-based furniture firm that experiences significant process waste (MUDA). Prabha’s flagship product line includes coffee tables, outfeed tables, indoor sofas, and indoor chairs. This study focuses on these products, drawing conclusions

Table 2. Product details and gain

Furniture type	Gain of the review	Paper Number
Household furniture.	Obtained a product functional design attribute, those common to the furniture.	[13]
Prototype plywood wardrobe.	The extent of satisfaction level owing to the new prototype among the TRs. The level increment from 2.71 to 4.08 points has been noted.	[14]
Computer workstation.	The aspects of increased customer satisfaction from the furniture’s value perspective.	[15]
Wood frame furniture.	Insights applied to outdoor wooden furniture design in campus space.	[16]
Drafting table for Engineering students.	Product design quality attributes- weight and odor.	[17]
Children’s rocking chair.	Utilization of QFD, TRIZ, and FEM towards improvement of design efficiency. Principle of separation in TRIZ.	[18]
Smart dining table.	Smarter design aspects for general customers- Ease of cleaning.	[19]

Table 3. Process MUDAs and equivalent INR conversion

Year	Process MUDA time (in hours)	Equivalent conversion (in INR)
2019	739	55,425.00
2020	877	70,160.00
2021	775	69,750.00
2022	816	77,520.00
2023	776	77,600.00
Average number of hours per year	797(Rounded value)	

based on data collected between 2019 and 2023. A pilot study conducted at Prabha revealed that manufacturing processes have been plagued by MUDA for several years, resulting in an annual loss of 797 clock hours. This loss equates to the potential production of 106 additional chairs, representing a missed profit opportunity of INR 1,69,600. Given the high demand for chairs within Prabha's core product range, it was selected as the baseline product for this analysis. Prabha's willingness to participate in this research aligns with the study's objective of exploring the Voice of the Customer (VOC) and Technical Attributes to enhance productivity.

Problem Statement

The furniture manufacturing processes were found to be inefficient, exceeding the standard cycle time and resulting in substantial financial losses. To address these inefficiencies, the researchers, along with Prabha employees (called 'team'), proposed a comprehensive approach that integrates Quality Function Deployment (QFD) with Lean Six Sigma methodologies. This integrated approach aims to optimize processes, reduce waste, and ultimately increase production capacity.

Objectives of the Research

The research study had the following primary objectives.

1. To generate the TRs with respect to the VOCs in the canvas of benchmarking outcomes in furniture craft.
2. To formulate the strategies in the process organization of selected processes, based on TRs.
3. To demonstrate the savings by elevating productivity.

Measurement of the Data

The second phase of the DMAIC (Define-Measure-Analyze-Improve-Control) process involved the study of past records of non-value-added time in processes (Process MUDA). The team converted it into monetary value using the operator rates provided by Prabha's costing executive.

The rates were:

Year 2019: INR 75.00 per hour, Year 2020: INR 80.00 per hour, Year 2021: INR 90.00 per hour, Year 2022: INR 95.00 per hour, Year 2023: INR 100.00 per hour. The process MUDA was observed in the range between 739 and 877 hours from the year 2019 to 2023. This is shown in Table 3.

Also, a comprehensive mapping of the furniture manufacturing processes was performed for the current year. A significant discrepancy was observed between the standard and actual process times for certain operations. To address this issue, a detailed analysis of thirteen processes from four flagship products was undertaken. These processes were selected based on a time value criterion, focusing on operations with a time gap exceeding 20% between the standard and actual times.

The process MUDA was observed consistently for a set of similar processes. The monetary loss due to the MUDA process was being ignored by Prabha. Table 4 describes the data for one of the batches out of past 6 batches observations. The batch having the lowest total actual time (i.e. 860 minutes) has been considered here.

Analysis

The data collected during the measurement phase revealed significant opportunities to reduce non-value-added (NVA) activities and improve productivity without compromising customer satisfaction. To understand customer needs and expectations (VOCs- Voice of Customers), survey reports from Prabha were analyzed. Additionally, a brainstorming session with the team and furniture experts from Prabha was conducted to identify key technical requirements (TRs).

VOCs were derived from customer concerns, considering factors like gender and occupation (male and female, business professionals and individuals). A check sheet was distributed to 70 exhibition visitors, and a weighted average of their responses was calculated, assigning a 60:40 weight ratio to female and male respondents, respectively. Input was also gathered from furniture designers and shop front-end sellers associated with Prabha. To finalize the VOCs, several criteria were considered, including product quality, customer satisfaction, and operational efficiency. A screening process was applied to identify the eight most significant VOCs. These VOCs were prioritized using a five-point Likert scale, with 1 representing the lowest priority and 5 representing the highest priority, as shown in Table 5.

In the case of various VOCs, strength was the essential one. This accommodates impact or a larger load. This is an essential feature for executive-class customers. The parameters- type of wood, balance, hardness, and porosity are related

Table 4. Processes with time values

Sr. No.	Product	Process	Time (minutes)	
			Standard time	Actual time
1	Coffee table	Gluing the top and shelf	32	46
2	Coffee table	Cutting the table legs	43	66
3	Indoor chair	Tapering the legs and armrest	72	96
4	Coffee table	Adding stretchers to table legs	62	78
5	Outfeed table	Attaching legs to the frames	38	52
6	Indoor chair	Cutting parts and assembling seat	58	79
7	Indoor chair	Cutting chair body to legs	52	83
8	Indoor chair	Joining the legs and armrest	8	17
9	Indoor sofa	Attaching sofa sides to the base	14	25
10	Indoor chair	Attaching cleats for chair slats	76	93
11	Indoor sofa	Attaching sofa sides to the base	3	12
12	Indoor sofa	Building sofa base	74	97
13	Indoor sofa	Assembling the sofa	84	116
Total			616	860

Table 5. VOCs with their priorities

VOCs	VOC Priority
Strength	5
Easy to move	3
Light weight	4
Suitable size and shape	3
Polish odor	5
Low maintenance	4
Resale value	3
Ease of cleaning	4
Priority Legend: 1. Extreme low, 2. Low, 3. Medium, 4. High, 5. Extreme high	

to this. The ease of movement of a furniture product and its weight correspond to the type of wood and porosity grade. A size and shape generate an aesthetic appearance, which relates to gravitational balance. Polish type plays an important role in terms of its odor, while maintenance and cleaning ease correspond to the type of wood and corrosion resistance.

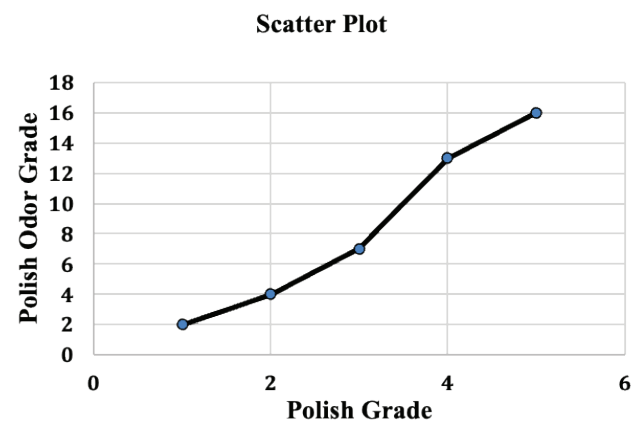
Technical Requirements (TRS)

TRs are key parameters, essentially needed in the product, which address VOCs. TRs, generated through brainstorming, were used subsequently in QFD. The nine TRs were:

1. Type of wood, 2. C.G. and balance, 3. Polish Grade 4. Porosity Grade, 5. Surface hardness, 6. Corrosion resistance (for metal hardware), 7. Smell level of polish, 8. Cost fluctuation index, 9. Coefficient of friction

Analyze VOCs and Link them with TRS

A Quality Function Deployment (QFD) matrix framework was employed to analyze the relationships between VOCs and TRs. VOCs were prioritized, and correlations between pairs of VOCs and TRs were assessed. Some relationships were evaluated based on prior experience, while others were visualized and analyzed using scatter plots and regression analysis in Minitab software. The Pearson Correlation Coefficient, calculated using Minitab, was used to quantify the strength of these relationships. For instance, a correlation coefficient of 0.9 was observed between polish and polish odor grade, while a correlation of -0.9 was found between porosity grade and strength grade. An absolute value of 0.9 was used in the QFD calculations. Scatter plots, as depicted in Figures 2 and 3, were used to visualize these correlations with historical data.

**Figure 2.** Scatter plot- polish grade, polish odor grade.

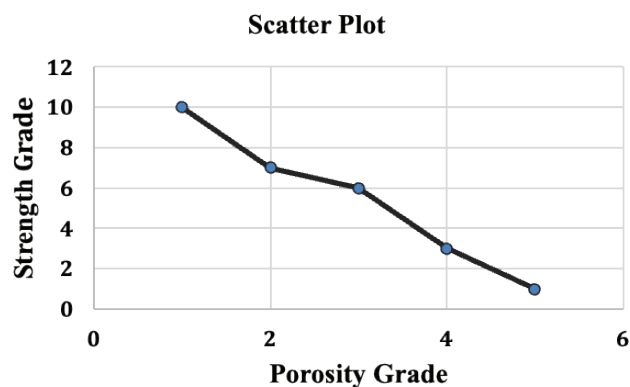


Figure 3. Scatter plot- porosity grade, strength grade.

Benchmarking

Based on quality functions, a decision was taken to benchmark Prabha Furniture's current performance with competitors' performance. Among the various competitors, Mitta Furniture, which possesses the biggest market share in the given product category, was selected as an ethical performance benchmarking partner.

The team takes the support of benchmarking consultants. They do the comparison with other brand products. A discussion was made with respect of VOCs- Strength, Easy to move, etc. A common understanding of VOCs was established during the benchmarking discussions. Benchmarking revealed the extent of customers' requirements met by Prabha and Mitta Furniture in coffee tables and sofas (a common product in attributes, category, and value). The numbers '1' through '5' were listed in the competitor rating. A rating value of '1' was assigned to weak performance, while '5' was assigned to superior performance. A scale of 1 to 5 was introduced in the QFD matrix, with a legend of a triangular symbol and a square symbol, against the 1 to 5 number scale. A triangular symbol was considered for Prabha, while the square symbol was for Mitta Furniture.

Preparing QFD

QFD was performed to enhance an organization's ability to communicate, document, analyze, and prioritize the TRs. QFD translates customer needs into engineering design characteristics through the integration of marketing, design, engineering, manufacturing, and other relevant functions of the organization.

The QFD discipline provides both a framework and a structured process to enhance an organization's ability to communicate, document, analyze, and prioritize [20]. QFD was performed through a graphical technique called House of Quality (HOQ) that involves a left window for describing customer needs (VOCs), a right window for giving competitor analysis, a central part for displaying correlations, a ceiling for describing the TRs, and the roof for describing the interrelations.

QFD's central part contains the correlation values between each pair of VOCs and TRs. The team indicated the correlations by symbols, with **, *, and O, with the consideration of correlation (code) values 9, 4, and 1, respectively. The values selected encompass three discrete stage numbers on a scale of 1 to 10. Importance rating was calculated by summing the product of the correlation-coded value with the customer priority value. (e.g. Importance rating for- Type of wood = $(5 \times 9) + (3 \times 4) + (4 \times 9) + (3 \times 0) + (5 \times 1) + (4 \times 9) + (3 \times 9) + (4 \times 1) = 165$). Customer priority values were considered on a scale ranging from 1 to 5, in the consideration of lowest to highest, respectively.

The triangular-shaped roof part, shown at the top level of QFD in Figure 4, indicates interrelations among the TRs. The same sign convention- **, *, and O and their respective values- 9,4, and 1 were applied here [22]. The interrelation between the two TRs is known by tracing a triangular path on the roof. For example, the type of wood and porosity grade have a strong interrelation 9, as indicated by a filled circle. A QFD generated by the team is shown in Figure 4.

Interpretations From QFD

- Type of wood, Porosity grade, and Surface hardness have the highest importance rating. Extending the action on these TRs fulfills VOC to the largest extent.
- Roof of QFD indicates a strong interrelation among- Type of wood, Porosity grade, and Surface hardness. Hence, we can conclude that working only on the Type of wood shall cover the other two TRs- Porosity grade, and Surface hardness.
- The right-hand window indicates competitor ratings. A most prior VOC- 'strength' (having priority level 5) is rated 3 with Prabha. It has a rating value of 5 with Mitta furniture. Strength can be increased by adopting the attributes observed with Mitta Furniture products. The respective TR- i.e. Type of wood can be suitably worked out to achieve this.

Selection of the Type of Wood

An opinion survey was conducted to choose the type of wood for the products, specifically the coffee table, outfeed table, indoor chair, and indoor sofa. Expert opinions were solicited from five respondents possessing expertise in furniture production procedures. Respondents were requested to choose the type of wood based on four critical attributes: Strength, weight, maintenance cost, and resale value [23].

The QFD analysis has discovered pertinent technical requirements (TRs) and voice of the customer (VOCs). The selection of these four traits was predicated on this. The rationale for selecting the qualities was to encompass the merging of TRs and VOCs. It was surface hardness correlated with strength, and porosity grade associated with weight. These traits, along with the additional two, maintenance cost and resale value, indicate the type of wood.

The opinion poll was taken independently for each furniture product. The 'Modal value' (Majority option) of



According to the modal value of the opinion poll shown in the table, mahogany wood was chosen to be used in the furniture as it had the largest preference (3 times out of 4 times). A due focus was given on Strength, Maintenance cost, and Resale value, while 'Weight' was considered

The peer team decided Mahogany wood from the available wood options for the coffee table. The decision was taken by the peer team based on various parameters as shown in Table 8. A similar approach was followed for selecting wood for other products- an outfeed table (plywood), an indoor chair, and an indoor sofa (cedar wood). The opinion poll selection matrix is shown in Table 8 and Table 9.

Product	Options
Coffee table	Mahogany, Oak, Ash and Maple wood
Outfeed table	Plywood, Fiberboard, Particleboard, Medium Density Fiberboard
Indoor chair and Indoor sofa	Cedarwood, Pinewood

Table 7. Opinion poll of 5 respondents for coffee table

Attributes				
Respondent	Surface hardness (Strength)	(Porosity grade) Weight	Maintenance cost	Resale value
1	Mahogany wood	Ash wood	Mahogany wood	Mahogany wood
2	Mahogany wood	Ash wood	Mahogany wood	Mahogany wood
3	Oak wood	Maple wood	Ash wood	Mahogany wood
4	Mahogany wood	Ash wood	Mahogany wood	Mahogany wood
5	Mahogany wood	Ash wood	Mahogany wood	Mahogany wood
Modal value	Mahogany wood	Ash Wood	Mahogany wood	Mahogany wood

Table 8. Opinion poll for the out feed table

Respondent	Surface hardness (strength)	(Porosity grade) weight	Maintenance cost	Resale value
1	Plywood	Particle board	Plywood	Plywood
2	Plywood	Particle board	Fiberwood	Plywood
3	Plywood	Plywood	Medium Density Fiberboard	Plywood
4	Plywood	Plywood	Plywood	Plywood
5	Fiberboard	Plywood	Plywood	Plywood
Majority	Plywood	Plywood	Plywood	Plywood

Table 9. Opinion poll for indoor chair and indoor sofa

Respondent	Surface hardness (strength)	(Porosity grade) weight	Maintenance cost	Resale value
1	Cedar wood	Pine wood	Cedar wood	Cedar wood
2	Pine wood	Pine wood	Pine wood	Cedar wood
3	Cedar wood	Cedar wood	Pine wood	Cedar wood
4	Cedar wood	Cedar wood	Pine wood	Cedar wood
5	Cedar wood	Cedar wood	Cedar wood	Pine wood
Majority	Cedar wood	Cedar wood	Pine wood	Cedar wood

Improve Phase

Following the analysis and determination of the wood choices, the team concentrated on enhancing the processes. The manufacturing characteristics, including workmanship capabilities, tool types, surface finish production, and cutting ability, were closely aligned with the critical technical requirements. Workplace organization, utilizing the Lean methodology 5S, was implemented, and MUDAs were addressed following the principles of Poka Yoke, Kaizen, and Kanban.

Improvement in Coffee Table

To devise the actions, a macro process chart was prepared for the coffee table that contained the processes: 1. Gluing the top and shelf, 2. Cutting the table legs, 3. Making sides, 4. Adding stretchers to table legs, 5. Preparing table

top, 6. Dry fitting and 7. Finishing and assembling the table. A study of the macro process chart revealed a few options to curtail the processing time with respect to the tapering jig of the coffee table. Four significant options were chosen from brainstorming, and four respondents rated the options. The rating matrix was prepared as given in Table 10.

A rating score of 4 means the solution will effectively solve the problem. A score of 1 means the solution is irrelevant and does not solve the problem. Option 4 (Making a new tapering jig) was the best as the total rating score was the highest, i.e.14

The suggested option was followed, and the respective SOP (Standard Operating Procedure) was created to incorporate sustenance. An SOP for making a new Tapering Jig was formed as below- Step 1: Cut a piece of plywood, Step 2: Attach support on it, Step 3: Add

Table 10. Rating matrix

Options		Team members				Total Rating score
		1	2	3	4	
1	Outsourcing the tapering jig	4	1	1	3	9
2	Purchasing a new tapering jig	1	2	2	1	6
3	Sharing the same tapering jig	3	3	3	2	11
4	Making a new tapering jig	2	4	4	4	14

Table 11. Hurdles and MUDAs

Processes description	Hurdles in processes	MUDA Type
Cutting parts and assembling the Seat	Difficulty in preparing back assembly	Motion
Cutting and tapering the legs and armrest	Tapering jig settings	Overprocessing and waiting
Joining the legs and armrest	Usage of bandsaw involving more steps to perform shaping	Overprocessing
Shaping the DIY		
Attaching cleats for DIY slats	The discrepancies observed in assembly and finishing process.	Rework
Applying finish to DIY		
Connecting chair body to legs	Extra movement of the product and the operator during assembly.	Processing

registration blocks to make repeatable tapers and cut, Step 4: Apply a piece of tape to the jig, Step 5: Apply a piece of tape to the block, Step 6: Apply glue on the piece of tape of block, Step 7: Press the glued block on the piece of tape of jig.

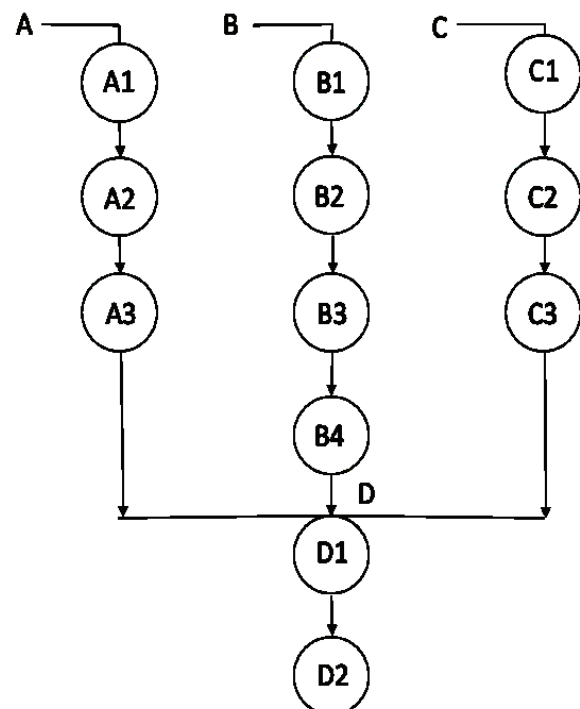
Improvement in Indoor Chairs and Other Products

To identify process MUDAs in the manufacturing process of chairs, the team did a brainstorming activity and investigated various hurdles concerning MUDAs, presented below in Table 11.

To understand the flow and sequence of the assembly process, a flow chart was prepared as shown in Figure 5.

The flow chart and the hurdles brainstorming were an informational and logical background for the team to implement certain actions, which fulfilled the VOCs and aligned with the TRs. Certain action elements for the out-feed table and indoor sofa were extracted from the benchmarking activity and are stated in the same table.

From the reference of these exercises, various improvement actions were taken, and a time study was conducted before and after the action was taken. Table 11 shows time elements, implemented actions for 13 key processes, and cost savings after the improvements. Cost saving was calculated by considering a labor rate of Rs.100 per hour. Table 12 below describes the data for one of the batches out of the 6 batches observed. The batch having the highest total actual time (i.e.678 minutes) has been considered here.

**Figure 5.** Flow chart of the chair process

A: Seat and seat sides: A1: Cutting, A2: Drilling, A3: Securing

B: Back uprights: B1: Cutting, B2: Cutting, B3: Laying, B4: Cutting

C: Back top rail and back bottom rail: C1: Cutting, C2: Drilling, C3: Clamping and, securing,

D: Back and seat: D1: Securing, D2: Clamping

Table 12. Processes with time values after the improvement

Product	Processes	Actions performed	Time (minutes)			Time saved (minutes)	Cost saved (INR)
			Ideal time	Actual time			
				Before improvement	After improvement		
Coffee table	Gluing the top and shelf	Use of alignment aids	32	46	38	8	13
Coffee table	Cutting the table legs	Tapering jig settings	43	66	47	19	32
Indoor chair	Tapering the legs, armrest		72	96	78	18	30
Coffee table	Adding stretchers to table legs	Drilling hole offset	62	78	65	13	22
Outfeed table	Attaching legs to the frames	Improved attachment	38	52	39	13	22
Indoor chair	Cutting parts and assembling seat	Assembly modification	58	79	65	14	23
Indoor chair	Cutting chair body to legs		52	83	59	24	40
Indoor chair	Joining the legs and armrest	Band saw cutting	8	17	10	7	12
Indoor sofa	Attaching sofa sides to base		14	25	15	10	17
Indoor chair	Attaching cleats for chair slats	Assembly and finishing to retain polish grade	76	93	78	15	25
Indoor sofa	Attaching sofa sides to base	Use of anti-corrosive dowel joineries	3	12	5	7	12
Indoor sofa	Building sofa base	Assembly enhancements	74	97	83	14	23
Indoor sofa	Assembling the sofa		84	116	96	20	33
Total			616	860	678	182	304

Control

Six Sigma DMAIC methodology emphasizes sustaining the improvements to avoid rework. Currently, internal and external audits are being performed with Prabha. Internal audit is conducted every day at the start of the shift by the Management Representative (MR) for 5S, while external audit is conducted monthly by an appointed consultant. The audit involves an assessment of 5S implementation, catering to a comprehensive background checklist that tries to demonstrate the application of various Lean principles concerning 5S.

RESULTS AND DISCUSSION

This research has integrated Voice of Customer (VOC) with thirteen essential processes through mediating Technical Requirements (TRs). Unlike traditional Lean approaches that often focus solely on bottleneck processes, this study considered both the Voice of Customer and Technical Requirements to identify improvement opportunities. By incorporating customer needs into the

productivity enhancement process, Prabha adopted a more competitive stance, aligning with customers' requirements while simultaneously increasing production. The research resulted in improved productivity and reduced processing time. The productivity enhancement was calculated by subtracting the post-implementation duration (678 minutes) from the pre-implementation duration (860 minutes).

A one-sample t-test was conducted using Minitab software at a 5% significance level to determine the statistical significance of the reduction in process time. The new time value of 678 minutes was compared to a hypothesized value of 860 minutes for a sample size of 6, with a standard deviation of 45.8 minutes. The resulting p-value was significantly less than 0.05, indicating a statistically significant reduction in time. A sample size of 6 repetitions was deemed sufficient to capture process and operator variability within the specific context of Prabha's operations. However, it is important to note that sample size and standard deviation may vary across different organizations. The reduction of 182 minutes from the original 860 minutes represents a

Table 13. Consolidated result sheet of a bifurcation of the total time saved

Product	Yearly orders	Time saved per unit (minutes)
Coffee table	192	40
Outfeed table	96	13
Indoor chair	216	78
Indoor sofa	144	51
Total		182

Table 14. Time and cost savings

Product	Yearly orders (a)	Time saved per unit (minutes) (b)	Total time saved in a year (minutes) (a x b)
Coffee table	192	40	7680
Outfeed table	96	13	1248
Indoor chair	216	78	16848
Indoor sofa	144	51	7344
Total		182	33120 (i.e. 552 hours)

21.16% decrease in process time, leading to a corresponding 21.16% increase in productivity. This change has been proven to be a significant change, as validated through a t-test. Many studies have been made that demonstrated the benefits of using the Lean or Six Sigma approach, the one referred to previously in the literature review, stating a 66.5% saving in a panel cutting process [21]. However, by incorporating QFD, the time saving in the processes has been a unique example, hence beyond comparison. Under conventional situations, i.e., by employing a Lean practice, several studies have reported a significant productivity boost; however, the use of QFD via VOC for productivity improvement has been reported beneficial.

The integrated application of Quality Function Deployment (QFD) and Lean methodologies proved effective in significantly enhancing furniture productivity. The results are summarized in Table 13.

Lean and Six Sigma tools and techniques can be effectively employed to achieve operational excellence in furniture manufacturing. This case study demonstrates the successful application of a collaborative Lean Six Sigma Define-Measure-Analyze-Improve-Control (DMAIC) approach to optimize workplace organization, improve process efficiency, and eliminate non-value-added activities - MUDAs. The research resulted in significant cost savings, as detailed in Table 14.

Cost saving per year (INR) = 552 hours x INR 100 per hour = INR 55,200.00

The average labor and other resources rate is INR 100 per hour, assumed here.

Hence, we can conclude through this real-time data evidence that the use of Quality Function Deployment (QFD)

towards enhancements in productivity and the subsequent benefits in cost savings is significant.

CONCLUSION

This study is beneficial to Micro, Small and Medium Enterprises (MSMEs) to investigate appropriate design parameters and link them to their process aspects. Many Micro, Small, and Medium Enterprises (MSMEs) have major concerns about their productivity and face challenges to achieve this rationally. The use of Quality Function Deployment (QFD) towards productivity has been demonstrated in this study and shall stand as a useful reference for Managers of Micro, Small, and Medium Enterprises (MSMEs) as well as for their consultants. This study shall help researchers to further investigate the use of additional Lean tools to integrate in Quality Function Deployment (QFD). Referring to the concepts of this study, functions other than manufacturing can be validated with Quality Function Deployment (QFD). A correlation with the customer satisfaction index and productivity can also be studied by employing QFD. The study correlates design parameters with manufacturing aspects, the one observed in the manufacturing category. This study may possess limitations to account for the situations in service industries.

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AUTHORSHIP CONTRIBUTIONS

Authors equally contributed to this work.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

STATEMENT ON THE USE OF ARTIFICIAL INTELLIGENCE

Artificial intelligence was not used in the preparation of the article.

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